
Office of Naval Research
ONR
Science & Technology
SEA-BASED AVIATION
N206HX
AUTONOMOUS SYSTEMS
ELECTROMAGNETIC &
HYPERSONIC WEAPONS
DIRECTED ENERGY
BF-03
SEA STRIKE
NAVAL AIR
WARFARE
AND
WEAPONS

SEA-BASED AVIATION, INCLUDING PLATFORM AND WEAPONS RESEARCH, IS FOCUSED ON NEW OR ENHANCED CAPABILITIES TO DEFEND AGAINST, AND/OR DETER, DISABLE, DAMAGE, DEFEAT OR DESTROY ADVERSARIES AT EXTENDED RANGES AND SPEEDS.

The Office of Naval Research (ONR) serves as the Department of the Navy's science and technology (S&T) solutions provider for the Navy and Marine Corps. Our mission, defined by law, is to "plan, foster and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power and the preservation of national security," and to "manage the Navy's basic and applied research, and advanced technology development to foster transition from science and technology to higher levels of research, development, test and evaluation."

The Naval Air Warfare and Weapons Department (Code 35) supports Navy and Marine Corps needs, fostering basic and applied research and advanced technology development in support of the Sea-Based Aviation National Naval Responsibility as well as directed energy, electromagnetic launch and high-speed conventional air and surface weapons.

This booklet highlights an assortment of the program areas being investigated within Code 35. These broad areas incorporate discoveries and inventions made across government laboratories, universities and industry. The following pages will provide insight into how these investigations interrelate scientific advancements with military objectives. If you have any questions or would like more information on any individual effort, ONR program officer contact information is provided.

Thank you for your interest in helping define the future of Naval Air Warfare and Weapons.

Dr. Thomas J. Beutner
Department Head
Naval Air Warfare and Weapons (Code 35)

Naval Air Warfare and Weapons

The Office of Naval Research (ONR) was established as an Echelon 1 command with the Chief of Naval Research (CNR) reporting to the Secretary of the Navy to sponsor scientific research that will enable future operational concepts of the Navy and the Marine Corps.

As the Department of the Navy's science and technology provider, ONR identifies S&T solutions to address Navy and Marine Corps needs. Since its establishment in 1946, ONR continues to address emerging technology issues and challenges.

ONR manages the diverse naval S&T portfolio to:

- Address enduring naval needs
- Maintain investments and intellectual capital in areas unique to the Navy and Marine Corps
- Promote a culture of innovation across the naval services
- Encourage new researchers and stimulate competitive research contributing to the naval mission
- Seek partnerships with academia and industry that enhance S&T outputs
- Encourage informed risk-taking and learn from experiments
- Provide pathways for transitioning S&T outputs, including interactions between the S&T community and potential technology users in early stages of development
- Identify and leverage global technological advances
- Counter technological surprise and hedge against uncertainty

Within ONR there are six codes, or departments, responsible for meeting emergent warfighter needs:

Code 30: Expeditionary Maneuver Warfare and Combating Terrorism
Code 31: Command, Control, Communications, Intelligence, Surveillance and Reconnaissance (C4ISR)
Code 32: Ocean Battlespace Sensing
Code 33: Surface Warfare and Weapons
Code 34: Warfighter Performance
Code 35: Naval Air Warfare and Weapons

This booklet focuses on Code 35, Naval Air Warfare and Weapons. Code 35 is responsible to the CNR to provide overall leadership and management of the Department of the Navy's S&T program in assigned areas to include emerging technologies and demonstration opportunities in autonomous air systems, directed energy, surface- and air-launched weapons, and sea-based rotary and fixed-wing aviation.

Within these areas, Code 35 investment is further broken down by the maturation level of the area being investigated. There are three basic categories of funding within the code:

Discovery and Invention (D&I) consists of basic research (Budget Activity (BA) 6.1) and early applied research (BA 6.2). This part of the portfolio creates new fundamental knowledge that by design has a broad focus with a long timespan, from five to 20 years, needed to mature discoveries. Its programs are selected based on potential naval relevance and technology opportunity. D&I investments are the essential foundation required for advanced technology and they leverage other service, governmental, department, industry, international and general research community investments.

Leap Ahead Innovations include Innovative Naval Prototypes (INP). These are technology investments that are potentially game-changing or disruptive in nature. INPs achieve a level of technology suitable for transition in four to eight years. Leap Ahead funding comes from both applied research (BA 6.2) and advanced technology development (BA 6.3).

Future Naval Capabilities (FNC) technologies that deliver in about three years. The FNCs mature technology into requirements-driven, transition-oriented products. FNCs provide enabling capabilities to fill gaps in the Office of the Chief of Naval Operations and Marine Corps Combat Development Command requirements analyses identified in the Navy and Marine Corps.

The following pages detail the individual investment areas. Each page lists the Code 35 program officer responsible for executing developments within that area. You are encouraged to contact us to become involved and help to ensure that our warfighter is never in a fair fight.

Naval Air Warfare and Weapons Enduring Research Responsibilities

Directed Energy (DE) & Counter DE
- High Energy Lasers (HEL)
- Ultra Short Pulse Lasers (USPL)
- High Power Microwave/Radio Frequency (HPM/HPRF)
- Counter Directed Energy Weapons (CDEW)

Aerodynamics
- Fixed Wing
- Rotary Wing
- Vertical/Short Take-off & Landing (V/STOL)
- Modeling & Simulations of Air Vehicle and Ship Interactions

Flight Dynamics & Control
- Aerodynamic performance ranging from baseline efficiency to maneuvering capability
- Control law architecture, synthesis and analysis to achieve robust performance and stability
- Guidance and navigation in GPS-denied environments
- Cooperative control of multi-body systems

Propulsion
- Thermodynamic cycles for high speed and long endurance
- High stage-loading and efficient turbo machinery, including distortion tolerant fans
- Thermal management for engines and auxiliary systems
- Materials, coatings and manufacturing science for hot and cold section engine components
- Jet noise reduction for tactical aircraft
- Small gas turbine and reciprocating engine components

Structures and Materials
- Metallic structures combined loading mechanics, corrosion fatigue, test methods, environmental material damage, electrochemical stress, localized damage evolution and structural protection
- Composite structures characterization and failure analysis, damage initiation and progression, environmental effects, constituent materials development for resins, fibers and 3D strength
- Advanced concepts for adaptive, reconfigurable structures, multifunctional surfaces, thermal durability, electrical functionality, EMI shielding and lightweight armor materials

Energetic Materials
- New approaches to novel materials that maximize molecular design, synthesis efficiencies and predicted stabilities to achieve performance goals
- Develop a new class of ingredients that can surpass the oxygen content of Ammonium Perchlorate
- Development of macroscopic mechanical and chemical models; an understanding of molecule dynamics; strength/reactivity correlations

High-Speed and Hypersonics
- Boundary layer physics in shock dominated flows around highly-swept or slender bodies
- Aero-thermo-elastic effects arising from control surface actuation at high speeds
- Hypersonic aerodynamic design tools that incorporate transition pathways, free stream noise, roughness and cooling
- Ultra high temperature materials and thermal protection systems (TPS)

Autonomy
- Distributed control of large numbers of heterogeneous unmanned systems in complex airspaces
- Safe, perception-based control in complex, unstructured and cluttered environments
- Verification and validation of advanced autonomy including biologically inspired methods, nondeterministic algorithms, decentralized control, organic perception within control/decision-making loops, and complex human interactions for both safety and mission competence
- Scalable, self-organizing, survivable, organizational structure/hierarchy of heterogeneous unmanned vehicles appropriate to naval mission domains
- Autonomous learning, reasoning and decision-making in unstructured, dynamic and uncertain environments
- Human interaction/collaboration including understanding intent and actions of human team members, adversaries and bystanders

ONR Code 35 Future Naval Capabilities (FNC) Program

FNCs mature technology for transition to naval acquisition programs. FNC efforts typically start at a technology readiness level (TRL) of four and conclude at a TRL of six.

Each FNC is aligned to an identified warfighting gap or warfighting capability, and it can deliver a distinct, measurable improvement that contributes to closing the corresponding warfighting gap. FNCs can contain one or a number of discrete but interrelated products that take into account or leverage science and technology (S&T) investments by other organizations such as DARPA, Navy and other service laboratories, Centers of Excellence and industry.

FNCs place great emphasis on the condition that proposed S&T meets the warfighter needs of the fleet and force. The selection process places a rigorous emphasis on buy-in by the relevant resource/requirements and acquisition communities. From the outset, it is imperative that FNCs have a clear transition path to the warfighter, and that each FNC is built upon a solid foundation of science and technology.

Research Challenges and Opportunities

- UAV autonomous operations, mission planning, dynamic re-planning command and control and multi-vehicle coordinated operations
- Air and surface-launched weapons and airborne precision targeting systems to include collaborative/network-enabled capabilities
- Directed energy components and countermeasures
- Air vehicle propulsion and rotorcraft aeromechanics
- Fixed and rotary-wing air vehicle structure, subsystems and flight control
- Vertical/short takeoff and landing systems and ship/aircraft interface
- Reduction in weapons and air platform lifecycle costs
- Increased availability of air assets and survivability systems
- Hypersonic technologies and weapons

AT A GLANCE

WHAT IS IT?
The Future Naval Capabilities (FNC) program – as an integral part of the larger ONR-wide FNC program – is focused on delivering S&T solutions within the department's core competencies to the warfighter.

HOW DOES IT WORK?
Each FNC seeks to develop quantified S&T deliverables (e.g., prototype systems, knowledge products and technology improvements) in response to validated Navy and Marine Corps requirements. New FNCs are competed on an annual basis and, once approved, typically do not exceed four years in total effort.

WHAT WILL IT ACCOMPLISH?
The Code 35 FNC program will provide the Navy and Marine Corps with S&T solutions for complex aviation warfare and weapons problems, and it will do this by addressing the difficult technology risks associated with various naval acquisition programs. The single most important metric for all FNC programs is putting the results of ONR's FNC investment in the hands of the warfighter.

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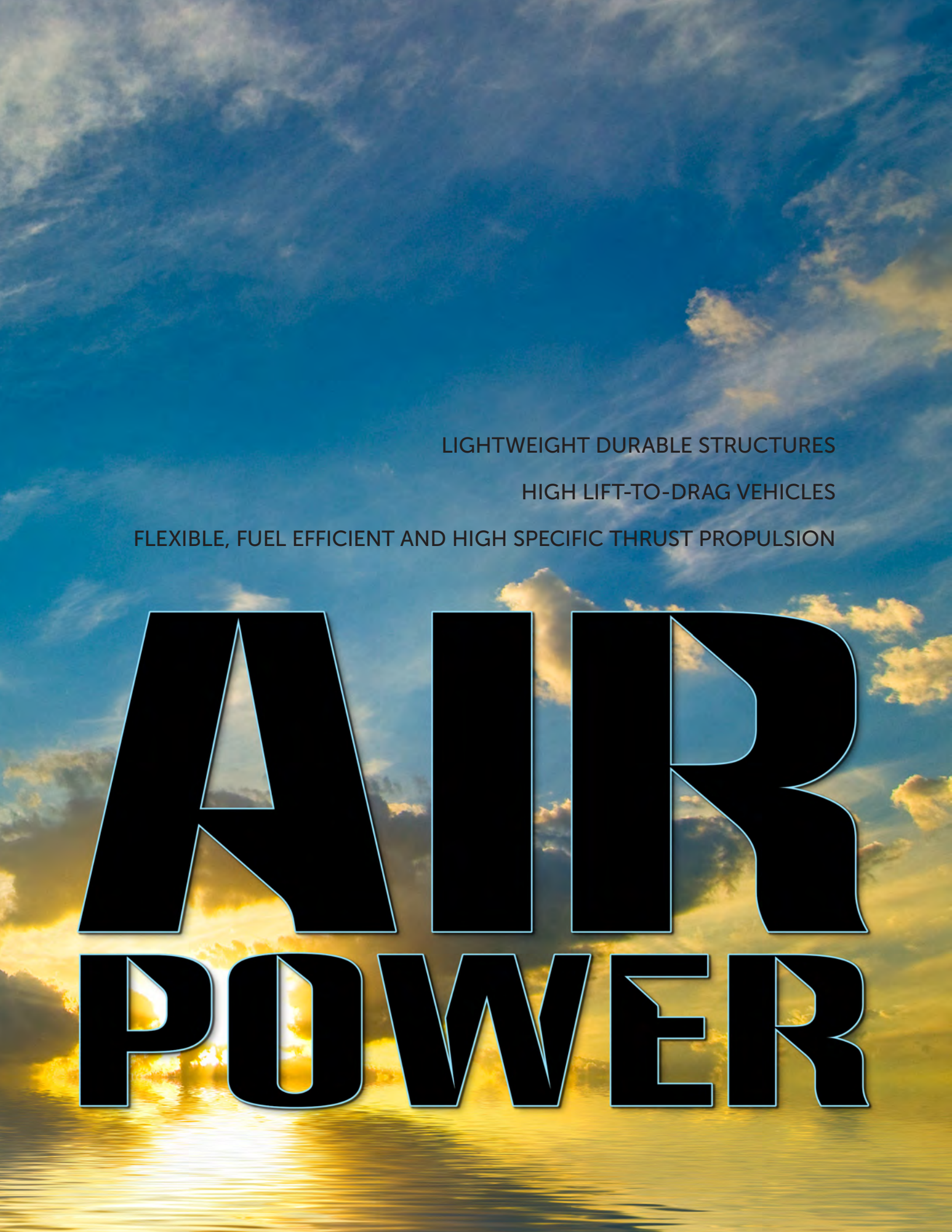
LIGHTWEIGHT DURABLE STRUCTURES
HIGH LIFT-TO-DRAG VEHICLES
FLEXIBLE, FUEL EFFICIENT AND HIGH SPECIFIC THRUST PROPULSION
AIR
POWER

Sea-Based Aviation National Naval Responsibility (SBA NNR)

The Office of Naval Research established Sea-Based Aviation as a National Naval Responsibility in 2011. NNRs are established to maintain the health, currency and technical superiority of areas critical to naval operations. In addition, the focused investments in these areas ensure a pipeline of students trained in areas of naval importance.

SBA includes the operation of aircraft to, from and on sea-based platforms. The maritime role of the naval aircraft is complex, demanding and unique. Operation aboard a ship has a dominant influence on the design of the aircraft. The dynamic interface between aircraft and ships requires a high degree of precision maneuvering to land on the moving ship deck in adverse weather and wind. The materials must resist a highly corrosive environment. The structure and configuration must be large enough to perform the mission while still having the ability to fold into a small footprint to be stored into small hangars, leaving enough room for critical maintenance. The air vehicle must be multi-mission capable for a diverse set of tasks.

Research Challenges and Opportunities:
- Aerodynamics
- Airframe structures and materials
- Power, propulsion and thermal management
- Flight dynamics and control
- Engine/Air-frame integration
- Ship interfaces and operations
- Guidance, navigation and control (GNC)
- Design tools
- Unmanned aerial vehicle launch and recovery

AT A GLANCE

WHAT IS IT?
- National Naval Responsibilities address research areas uniquely important to the Department of the Navy which are not addressed by research investments from the other military services.
- The Office of Naval Research (ONR) must ensure continuing U.S. leadership in these vitally important scientific and technical disciplines.

HOW DOES IT WORK?
ONR identifies certain technical areas as National Naval Responsibilities (NNR). ONR considers various scientific fields and assesses:
- The scope of naval responsibility
- Funding and funding trends
- The scope, degree, stability and trend of non-naval funding
- The scientific and technological performer base in academia, government and industry
- The scientific and technological infrastructure
- The scientific and technological knowledge base, including graduate and post-doctoral programs
- The prospects of integration with and transition to engineering development and acquisition programs.

WHAT WILL IT ACCOMPLISH?
- Above all, SBA NNR seeks to keep the fields healthy by sustaining research in critical areas for naval aviation.
- SBA NNR maintains the strength of key areas of basic and applied research, and it balances theoretical, empirical and field work to sustain a research infrastructure.

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Sea-Based Aviation National Naval Responsibility – Air Vehicle Science and Technology

The Navy and Marine Corps rely on fixed-wing, rotary-wing and vertical/short takeoff and landing (V/STOL) aircraft to perform and support a wide variety of missions, such as close air support, air defense, logistics, expeditionary operations, anti-submarine and anti-mine warfare, and search and rescue. The unique requirement to operate from ships at night and in bad weather and high sea states leads to a number of S&T challenges. Shipboard landings require precise relative navigation and ability to maneuver in highly turbulent ship airwakes and to land on pitching and rolling decks in high sea states. Shipboard operations also require unique designs to accommodate limited space and safe operations and support in densely packed areas. The Marine Corps depends on fast, agile air vehicles to execute its Ship-to-Objective Maneuver and distributed operations. These challenges require focused core investments, as well as close coordination and integration with other services and agencies that have substantial investments in air vehicle technologies.

The Air Vehicle Discovery and Invention (D&I) program invests in basic and applied research in both fixed- and rotary-wing vehicles. Emphasis is placed on naval-relevant issues requiring focused navy investment. An ongoing program in ship airwake prediction has yielded advanced methods and in-house naval expertise and has greatly enhanced the fidelity of piloted simulations of shipboard landings. Continued D&I focus in this area targets high-fidelity, fully-coupled ship/aircraft airwake models operating in real-time for implementation in piloted simulations and ship and aircraft design studies. Another research topic area considers rotorcraft aeromechanics, with projects currently in multicyclic blade control for vibration reduction, hub drag prediction and flow control.

Research Challenges and Opportunities:

- Computationally efficient analytical tools for ship/aircraft dynamic interface simulation
- Advanced control systems for carefree shipboard landings in challenging operating conditions
- Automated shipboard landings and deck operations
- Efficient, high-speed V/STOL concepts for sea-based operations
- Flow control for improved air vehicle aerodynamics
- Innovative experimental methods for ship airwake measurement

AT A GLANCE

WHAT IS IT?
Aircraft technology includes fixed-wing, rotary wing, and vertical/short takeoff and landing (V/STOL) vehicle technologies; ship/aircraft dynamic interface; air vehicle management and control; aerodynamics; aeromechanics; subsystems; and modeling, simulation and analysis tools.

HOW DOES IT WORK?
Core investments include:

- Advanced, efficient computational fluid dynamics techniques for modeling aerodynamics problems of naval importance such as ship superstructure airwake, coupled ship/aircraft aerodynamics and aircraft maneuvering in ship airwakes
- Wind tunnel and in-situ testing of ships in support of ship/aircraft dynamic interface studies
- Technology development, computational modeling and wind tunnel test of advanced V/STOL concepts
- Analytical and experimental investigations of rotorcraft handling qualities, including identification of favorable vehicle response types for operation in turbulent ship airwakes and control systems for carefree, near-ship maneuvering

WHAT WILL IT ACCOMPLISH?
Air vehicle technology will contribute to Navy and Marine Corps aircraft with enhanced performance, maneuverability and survivability; reduced operating and support cost; and suited to the particular needs and environments of Navy and Marine Corps missions.

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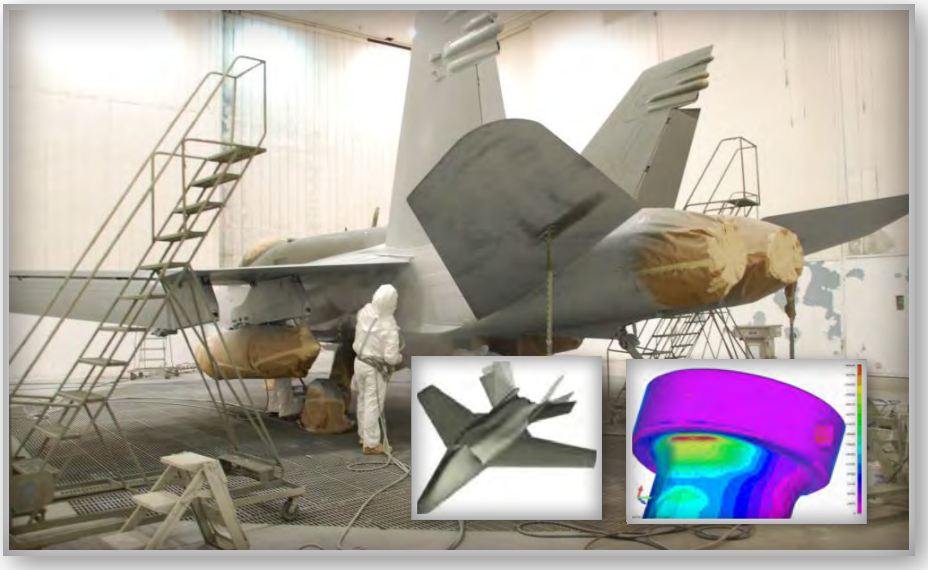
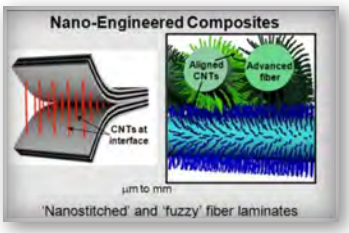


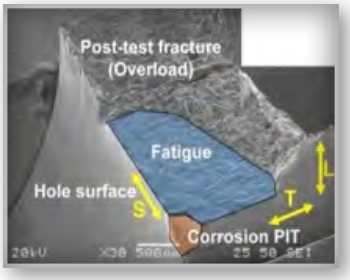
Sea-Based Aviation National Naval Responsibility-Structures and Materials

Naval aviation is in the forefront of the Navy's power projection mission. Sea-based operations pose structural and material challenges that are substantially different from land-based aviation requirements. A robust program that sustains a focused aircraft S&T activity with an underpinning of research, design, manufacturing and sustainment is critical to the health of naval aviation.

Under the ONR Sea-Based Aviation National Naval Responsibility, the Structures and Materials program will enable more robust aircraft design; reduce maintenance and sustainment impacts due to design decisions driven by weight or environmental factors; improve the fidelity of materials selection impact analysis and trade-off decisions; and enable reduced weight. The Structures and Materials program covers technical areas such as multi-functional materials; integrated structural and material degradation analysis; remaining life prediction; multi-scale fatigue and fracture prediction; optimized airframe materials selection; advanced composite materials research; advanced structural concepts; and modeling complex load and damage interactions.



Basic and applied research programs are being conducted in the areas of advanced concepts, durable aircraft development, structural analytics and prognosis, advanced material design, composites and composite repair and material coatings.



Research Challenges and Opportunities:

- Structural failure mode characterization
- High-loading, lightweight structural materials
- Advanced structural concepts
- Materials degradation/corrosion
- Structural protection and maintenance

AT A GLANCE

WHAT IS IT?
Metallic structures and materials, composite structures and materials, and advanced concepts related to: design, failure analysis, materials selection, fabrication and sustainment of air-vehicle structures. Airframe Structures and Materials Science and Technology addresses durability, service life, readiness, affordability and future capabilities development. Most airframe technology challenges are not platform or design specific; they are fully represented in both current new-build and planned next-generation platform designs.

HOW DOES IT WORK?
Core investments include basic and applied research funding with emphasis on transition to advanced technology development. Work is supported by naval aviation experts at the Naval Air Systems Command, Naval Air Warfare Center laboratories and the Naval Research Laboratory. Close coordination with the Air Force Research Laboratory, the Army Aviation Command and the Defense Advanced Research Projects Agency helps ensure that, in addition to Navy and Marine Corps unique technology needs, the investments of other services and agencies are leveraged and integrated.

WHAT WILL IT ACCOMPLISH?
Advanced airframe technology will address the following needs and environments of Navy and Marine Corps aviation in:

- Understanding and predicting the impact of material property degradation
- Developing advanced structure maintenance and repair methods
- Airframe structural life prediction and sustainment
- Integrated materials selection and design analysis
- High-strength, lightweight structural materials development for shipboard launch and recovery.

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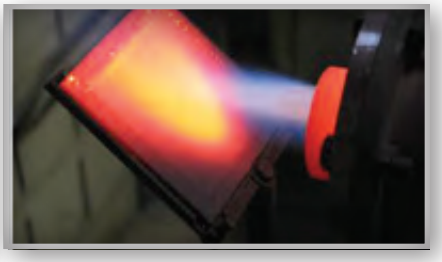

Sea-Based Aviation National Naval Responsibility – Power & Propulsion

Propulsion systems and their associated power and thermal management sub-systems are critical to the performance, operability, readiness and life-cycle cost of naval air vehicles. Specifically, the speed and range of fighter and strike aircraft is strongly dependent on the gas turbine engines and their specific thrust and fuel efficiency, respectively. In addition, turbine propulsion systems are the primary fleet readiness driver and are the largest cost in operational systems. Improvements in these propulsion-related systems have the greatest potential to increase aircraft range, speed, operability, readiness and other positive mission capabilities, while reducing life-cycle costs.

While there are many common aspects to increasing performance of propulsion systems for commercial aviation and other military needs, such as increased turbomachinery efficiency and higher turbine inlet temperature, the focus of this program is the investments on those technologies that are either naval-driven or Naval Unique. Aircraft carrier and other shipboard operations, as well as austere field operations for the Navy and Marine Corps create a very challenging set of operational constraints that are unique to the naval services. Specifically, the need for very high specific thrust for short or vertical takeoff along with supersonic speeds combined with the need for low thrust specific fuel consumption for longer range or endurance is one of the most unique requirements for naval aviation. In addition, the requirement to have an engine accelerate from a minimum thrust level on carrier approach to full-power operation in a matter of seconds should an aircraft miss the landing wires (bolters), is a unique aspect of naval aviation. Another set of issues faced by naval aircraft is the harsh environmental conditions with sea air, salt-spray and sand ingestion creating a number of erosion, corrosion, and related durability problems. Finally the Navy utilizes high flash point fuel (JP-5) that may introduce a number of material and combustion related issues.

The Propulsion focus areas will provide innovative research and technology in: propulsion cycles, subsystems and integration; turbo-machinery and drive systems with enhanced performance and maintainability; hot-section materials and coatings; small unmanned aerial vehicle propulsion and thermal management.

Research Challenges and Opportunities:

- Advanced high stage loading turbomachinery, including turbomachinery tip-flows and casing treatment, novel designs, etc.
- Engine-airframe integration, including active and/or passive flow control, as well as distortion-tolerant fans
- Advanced thermodynamic cycles, including pressure gain combustion, internal heat transfer, etc.
- Improved components and sub-systems, including seals, bearings, engine auxiliaries and externals, etc.
- Turbo-machinery rotodynamics modeling tools capturing transient/complex loading
- Technologies for increasing electrical power and thermal management capability
- Durable thermal/environmental barrier coatings for harsh environments
- Ceramic matrix composites for naval-unique operating conditions

AT A GLANCE

WHAT IS IT?
The Sea-based Aviation National Naval Responsibility (SBA NNR) Propulsion focus area is a long-term basic and applied research initiative having an objective to maintain the health, currency and technical superiority of Sea-Based Aviation science and technology (S&T) in propulsion-related technology areas.

HOW DOES IT WORK?
With academia, industry and naval aviation laboratories as its source of expertise, the SBA NNR Propulsion focus area will solicit the most innovative and technically sound research topics to fulfill its objective, then develop them through basic and applied research efforts leading to future S&T transitions for naval aviation.

WHAT WILL IT ACCOMPLISH?
The SBA NNR Propulsion focus area will provide the advanced propulsion, power and thermal management technologies supporting future naval aviation needs. In addition, it will support the technology infrastructure necessary to maintain technology superiority while serving as a pipeline of future scientists and engineers.

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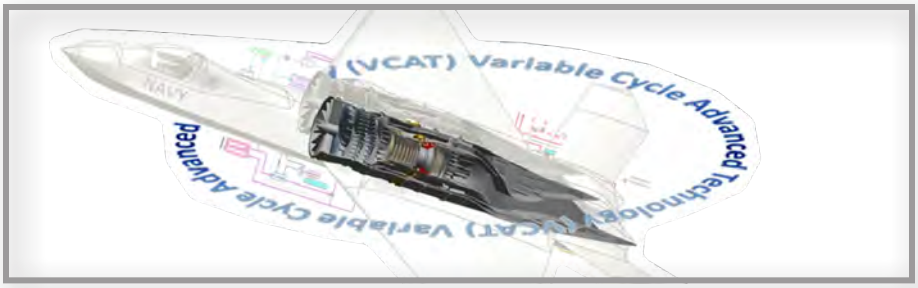

Next Generation Engine Enablers: Variable Cycle Advanced Technology (VCAT)

The Variable Cycle Advanced Technology (VCAT) program is a partnership effort between ONR and the Department of the Navy's Task Force Energy that advances variable and adaptive cycle turbine engine technology. Advancements in propulsion system technology are essential to meet desired warfighter needs for future carrier-based tactical fighter and strike aircraft. Traditional gas turbine engines are a less than optimal compromise between creating an engine that has high thrust for take-off and supersonic dashes for combat, while having sufficiently low thrust specific fuel consumption (TSFC) for long range. Specifically the configuration needed for high specific thrust requires a low engine bypass ratio, a moderate core compressor pressure ratio and a high through-flow turbine, while a high thermodynamic and propulsive efficiency cycle for long rage would drive a design to have a high fan bypass ratio and core compressor ratio, and a lower turbine flow rate. An adaptive cycle engine provides the ability to adjust the engine characteristic so higher thrust and speed can be obtained when needed, while retaining the ability to operate the engine in a more efficient mode during cruise operation.

In close coordination with the Naval Air Systems Command (NAVAIR) the overall Naval Aviation Enterprise (NAE) and the U.S. Air Force Research Laboratory (AFRL) the VCAT program objectives are to develop and mature variable cycle and adaptive turbine engine technologies for future carrier-based naval aviation systems. VCAT engine technology has shown in analytical studies the ability to significantly improve range and loiter capability for a wide range of platforms and missions, while retaining very high specific thrust capability that is required for takeoff and supersonic operations. The benefits are due to the variable cycle features and improved thermal and propulsive efficiencies from advanced materials and component technologies. This reduced fuel consumption also offers the potential for significant reductions in both annual fuel costs and logistics tail, due to less demand for deployed fuel and tanker aircraft support.

Research Challenges and Opportunities:
- Aerodynamic, mechanical and control of variable/adaptive engine technologies for naval aviation applications
- Adaptive fan technologies
- Aerodynamics and heat transfer in variable geometry high- and low- pressure turbines
- Advanced multi-input, multi-output (MIMO), and multi-objective, performance seeking controls
- Integrated and optimized mission, flight and engine control systems
- Structural and bearing loads from catapult and trap accelerations
- Low-speed thrust response for approach, wave-off and bolter
- Environmental and corrosion resistance in a marine environment
- Thermal and power management technologies

AT A GLANCE

WHAT IS IT?
The VCAT program will identify and mature critical, relevant variable/adaptive cycle turbine propulsion technology for future carrier-based tactical aircraft (TACAIR)/intelligence, surveillance and reconnaissance (ISR) systems, resulting in dramatic performance and capability improvements.

HOW DOES IT WORK?
- The VCAT is working with industry experts to conduct systems analyses and Navy-unique/important turbine engine technology development options for future naval aviation platform capability desires.
- These efforts are leveraging the Air Force's adaptive versatile engine technology, science and technology (S&T) demonstration effort. VCAT is a part of an overall integrated propulsion, power and thermal management system requiring further S&T maturation.

WHAT WILL IT ACCOMPLISH?
- Advancements in propulsion system technology are essential to meet desired warfighter goals for future carrier-based TACAIR/ISR systems.
- Enhanced energy security for naval aviation and the nation continues to be an important part of the VCAT program's vision for the future.

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Jet Noise Reduction (JNR)

The Jet Noise Reduction (JNR) Program is part of the Office of Naval Research's Noise-Induced Hearing Loss Program and is as a result of the health and environmental impacts of noise. Personnel supporting launching operations on the decks of aircraft carriers are subject to noise from the afterburning supersonic jet engines that can exceed 140 dBA. The purpose of this program is to better understand the physics of jet noise with the ultimate aim to reduce the near field noise by reducing, moving or shielding the sources from the people receiving this acoustic power.

The main parts of this program are developing a physics-based understanding of the fluid mechanics of the jet evolution, creating analytical and computational models and understanding of how these complex fluid flows create jet noise, and developing a standard and reproducible high-quality, supersonic, jet-noise measurements. A research effort focusing on the development of tools for the passive and active control of hot, supersonic jets is the ultimate goal.

The JNR project supports the development of fundamental tools that will enable the optimized design of noise-control systems for legacy, emerging and future tactical aircraft. The project examines noise mitigation approaches at all levels of technology maturity, both computationally and experimentally, and encourages research into new areas of noise control through theoretical development and experimental validation.

Research Challenges and Opportunities:

- Fluid mechanics of single and twin, supersonic, heat jets: instabilities, transition, turbulence and mixing
- Better understand how the various scales of turbulent structures lead to the generation and radiation of noise
- Statistical and deterministic methods in characterizing and understanding turbulence and jet noise
- Effective noise-source models for noise produced by large-scale jet structures in hot, supersonic jets
- Efficient and reliable time-resolved noise prediction tools
- Single- and multiple- scale modeling and computations
- Diffracting, shielding, and localizing away from undesired locations on the deck
- Design and inverse (adjoint) optimized problems with jet noise
- Validation data for theoretical and computational models
- Effective active and passive control strategies for exhaust noise reduction

AT A GLANCE

WHAT IS IT?
Through long-term research, the JNR project aims to understand the physics of jet noise produced by high-performance military aircraft; identify materiel/non-materiel solutions to reduce noise; and develop and transition technologies in support of the warfighter and the civilian community, especially nearby military bases conducting flight operations.

HOW DOES IT WORK?
Guided by a government-wide panel of science and technology experts,the JNR project:

- Supports the development of theoretical noise models, prediction tools, noise control strategies, diagnostic tools and enhanced-source localization and propagation techniques
- Proposes American National Standards Institute noise measurement standards for military aircraft.

WHAT WILL IT ACCOMPLISH?

- Improves the physical understanding of noise sources in supersonic jet exhausts from high-performance military aircraft
- Provides critical insight for the development of effective noise control strategies and associated noise reduction potential
- Provides fundamental tools to guide the design of future optimized noise-control systems
- Guides noise measurement requirements for naval aviation systems

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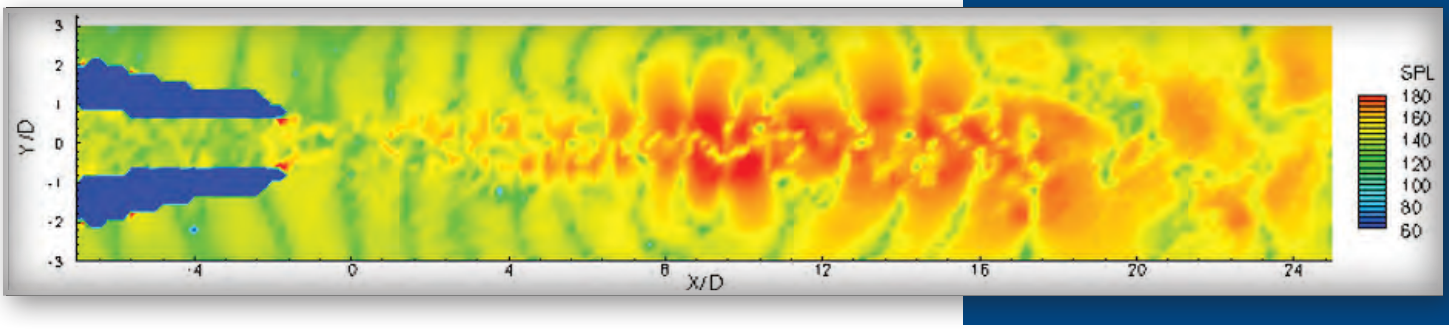

Advanced Topcoat System (ATS)

The ATS Future Naval Capability product is developing protective coating systems with substantially improved corrosion inhibition and reduced environmental, safety and health (ESOH) impacts for Navy and Marine Corps aviation weapon systems and Marine Corps ground and amphibious weapon systems. To achieve this, the ATS program is developing and integrating two technologies: a state-of-the-art topcoat system for aviation (AV) and ground and amphibious vehicles (GV). Performance advancements are focused on increased corrosion performance and optimizing coating deposition, adhesion and chemical agent resistance.

The ATS products are responding to higher performance corrosion requirements with reduced ESOH impact as expressed by the fleet. In addition to substantially reducing the impact of corrosion, the ATS products will reduce the use of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), as well as reduce flammability. All of these advances will improve the quality of the workplace for maintenance personnel.

By improving coating system performance, ATS will ensure that the Navy and Marine Corps reduce the impact of maintenance activities worldwide while employing state-of-the-art protection schemes, which enhance survivability over extended maintenance intervals. The ATS products enable increased Sailor/Marine operational health and safety and eliminate restrictions on corrosion prevention and control (CPaC) maintenance.

Key Technologies:
Non-isocyanate topcoats, with chemical-agent-resistant coating (CARC) option for the Marine Corps; lower VOCs, HAPs and flammability (AV and GV)—to address shipboard maintenance capability gap; aluminum-rich primer with capability for use on aluminum and steel; and larger range of applied thickness (AV and GV)—to address improved galvanic corrosion protection gap

Research Challenges and Opportunities
- Topcoat–novel, isocyanate-free polymers/catalysts
- Single–(1K) and two-component (2K) formulations
- Primer–novel galvanic protection pigments/inhibitors

AT A GLANCE

WHAT IS IT?
A primer/topcoat system that provides reduced toxicity to enable shipboard maintenance of aviation and amphibious platforms with high-performance structural protection

HOW DOES IT WORK?
- New topcoat resin chemistry to address maintenance operation restrictions associated with toxic isocyanate materials
- Novel metal-rich primers for improved protection of dissimilar material interfaces; weight reduction versus current zinc-rich pigments

WHAT WILL IT ACCOMPLISH?
Enhanced corrosion protection
- 25 percent reduction in corrosion and coating maintenance costs for naval aviation
- 35 percent reduction in maintenance cost for Marine Corps ground vehicles
- Provide improved functional performance and reduced toxicity
- Reduce health and environmental issues by elimination of toxic isocyanates
- Increase exterior color stability, gloss retention, flexibility and erosion resistance for aviation vehicles
- Increase retention of chemical warfare agent resistance, and mar/impact resistance for ground vehicles
- Reduce flammability by increasing flash point to 140°F; volatile organic compounds to 100 g/L

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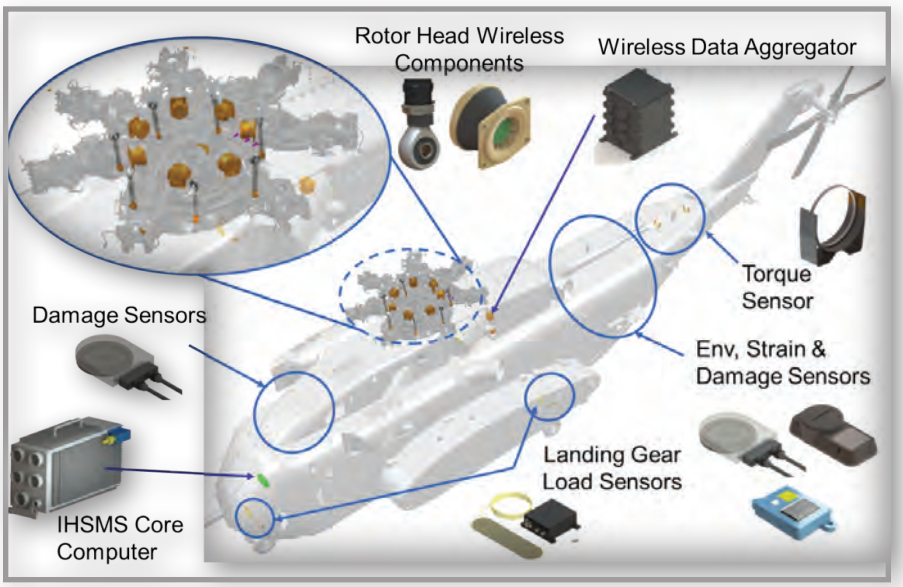

Integrated Hybrid Structural Management System (IHSMS)

The IHSMS Future Naval Capability product will deliver robust management decision tools to continue a shift away from the current deterministic, fixed-flight-hour-based maintenance practice to one based on the management of risk and reliability over an entire rotorcraft fleet. These capabilities are a key enabling technology for the implementation of the condition-based maintenance plus (CBM+) approach to rotorcraft structures. The CH-53K is the lead platform to transition the IHSMS technologies to the fleet.

Integrated, high-quality information enables adjustment of component retirement time and expansion of maintenance removal criteria. With IHSMS, maintenance criteria can be updated based on factual data, thereby reducing direct maintenance and spare part replenishment costs. IHSMS will enable integrated health monitoring of metal and composite aircraft structures, including rotor blades and airframes. In addition, it will calculate aircraft weight and center of gravity to speed loading operations and enhance safety. It will facilitate accommodation of aircraft growth and mission changes. And because helicopters are subject to some of the most severe operating conditions and present a worst-case scenario, the technologies developed in IHSMS should be adaptable to many other air, land, sea and undersea platforms.

The IHSMS development process includes the development of sensors, system architecture, and data processing units; laboratory integration and verification testing; and ground and flight validation testing to achieve a Technology Readiness Level of 6.

Research Challenges and Opportunities

- Very small, robust, wireless, energy-harvesting strain sensors
- Methods of sensor integration into metal and composite structures
- Architecture, algorithms and data processing to use sensor data locally and over the entire airframe for structural fatigue life determination and health management

AT A GLANCE

WHAT IS IT?
The IHSMS Future Naval Capability program will provide integrated global and local structural health monitoring technologies and advanced modeling capabilities that can be transitioned to Navy and Marine Corps rotorcraft.

HOW DOES IT WORK?
This effort will develop and demonstrate a network of small, wired and wireless, energy-harvesting sensors distributed throughout a helicopter's metal and composite structure. The system will gather and report strain, vibration, temperature and environmental data to a central processor for monitoring loads and environmental degradation to determine aircraft structural life and health.

WHAT WILL IT ACCOMPLISH?
Substantial cost savings and safety, readiness and operations enhancement:

- Extended parts flight-hour life and reduced maintenance through direct usage monitoring
- Enhanced safety and reduced reactive maintenance through early damage detection
- Enhanced safety and operational capabilities through preflight and real-time in-flight knowledge of weight and center of gravity
- More comprehensive understanding of failure modes of the vehicle
- Potential for real-time flight control corrective action input in case of over stress or battle damage encounters

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Tern

The Tern program will develop and demonstrate technologies for a new class of medium-size aircraft operating from DDG- and LCS-class ships. This vision capability will significantly enhance Navy intelligence, surveillance and reconnaissance (ISR)/strike capabilities by providing a fixed-wing, long-range/endurance aircraft operable from short deck ships to provide flexible ISR/strike coverage for a global fleet. For ISR missions,the vision system design goal is to provide a persistent orbit at 600 nautical miles or more radius with 500 pounds or more of payload, using aircraft operable from small-deck ships. The vision system must be capable of executing autonomous launch and recovery with minimal manning requirements. Compatibility with small-deck ship operations is an important attribute of the vision vehicle. This includes hangar compatibility, ability to transit from hangar to flight deck, and ability to conduct maintenance and provide supporting logistics in space-constrained, personnel-limited ship environments.

Tern will push beyond limitations of current vertical take-off and landing (VTOL) aircraft design. Current technology VTOLs are inefficient cruise vehicles and have limited flight endurance as a result. The transition from horizontal airplane flight to/from VTOL mode requires control at large angles of attack, which adds significant additional aerodynamic and controls design challenges. Furthermore, the combination of large wing and vehicle compactness present significant control challenges for precision landing at significant sea states. Onboard power must provide high-thrust operation for takeoff and landing operations and very efficient low-throttle operation to provide long endurance at cruise.

In 2018, Tern will culminate in full-scale launch, recovery and flight testing of a demonstrator vehicle that will be consistent with a tactical vehicle in size, mass, aerodynamics, propulsion and autonomous controls. Although not a production prototype, the vehicle will demonstrate the salient characteristics required to evaluate future applications of this new class of aircraft as an innovative solution to current and future Navy mission requirements.

Research Challenges and Opportunities:
- VTOL aircraft design
- Autonomous launch and recovery with minimal manning
- Wing in propeller slipstream, unsteady aerodynamics and high angle of attack rotor design and performance
- Engine and electrical power technologies to provide high thrust for VTOL operation and efficient low-throttle operation to provide long endurance at cruise

AT A GLANCE

WHAT IS IT?
Tern is a joint Defense Advanced Research Projects Agency-Navy program to develop and demonstrate vertical take-off and landing (VTOL) air vehicle technologies for long-endurance presence from small-deck, air-capable naval ships.

HOW DOES IT WORK?
- Complex, aerodynamics-enabled high lift-to-drag tail sitter VTOL configuration with large folding wings, hybrid helicopter-aircraft controls, efficient and/or hybrid propulsion and reconfigurable mission packages
- Combination VTOL capability with fixed-wing aerodynamic cruise efficiency
- Autonomous launch, landing and mission
- Co-exist with manned H-60s on DDG- and LCS-class ships

WHAT WILL IT ACCOMPLISH?
- Tern will enable a long-endurance air vehicle with a 500-pound payload at a 600 NM mission radius to operate from a DDG or LCS.
- Tern will provide situational awareness beyond that achievable with ship-based radars for missions such as intelligence, surveillance and reconnaissance, mine warfare, surface warfare and strike.

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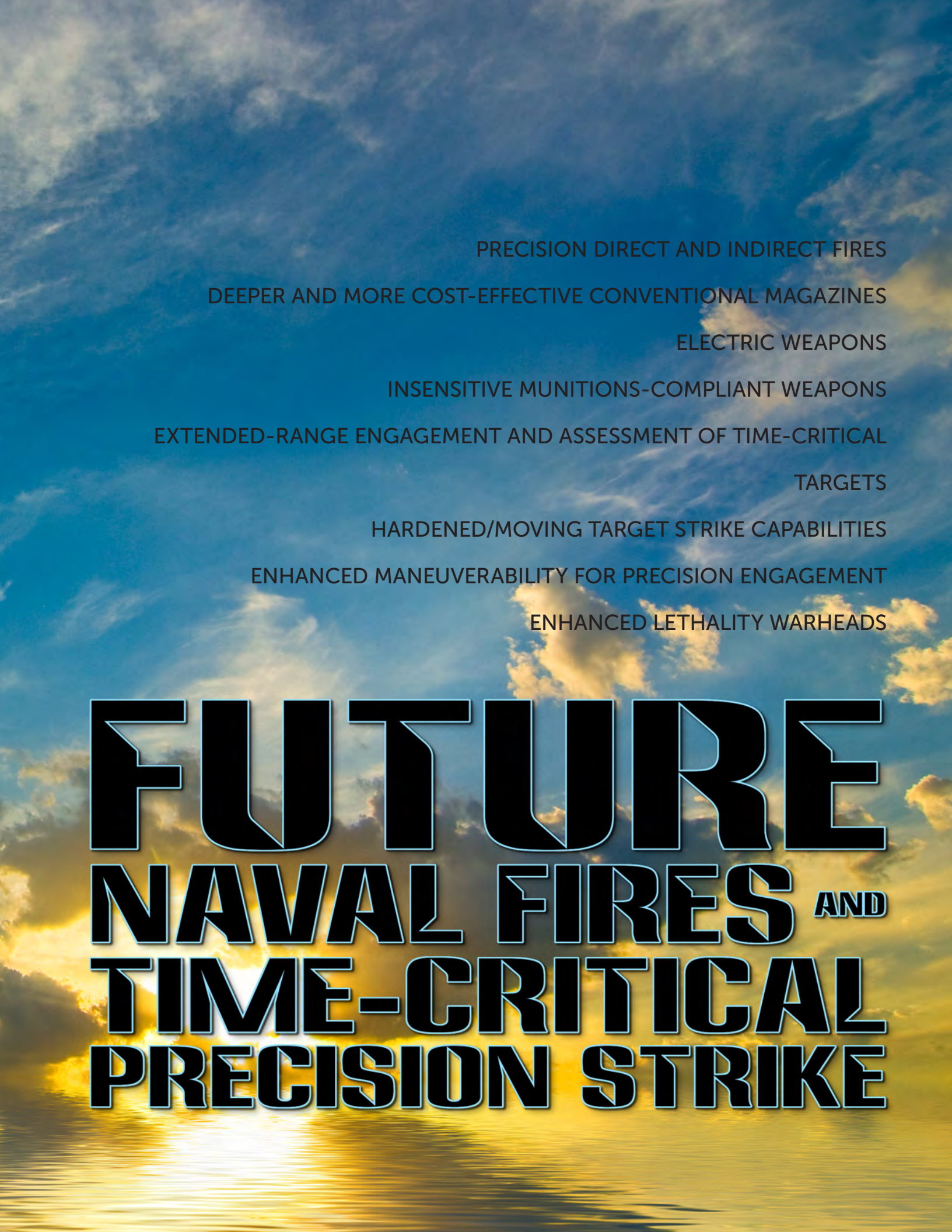
PRECISION DIRECT AND INDIRECT FIRES
DEEPER AND MORE COST-EFFECTIVE CONVENTIONAL MAGAZINES
ELECTRIC WEAPONS
INSENSITIVE MUNITIONS-COMPLIANT WEAPONS
EXTENDED-RANGE ENGAGEMENT AND ASSESSMENT OF TIME-CRITICAL TARGETS
HARDENED/MOVING TARGET STRIKE CAPABILITIES
ENHANCED MANEUVERABILITY FOR PRECISION ENGAGEMENT
ENHANCED LETHALITY WARHEADS
FUTURE NAVAL FIRES AND TIME-CRITICAL PRECISION STRIKE

USS Forrestal, July 29, 1967

Combat Safe Insensitive Munitions (CSIM)

The need for IM compliance
The Navy has grave concerns over conventional munitions and propellant systems, since all munitions are stored on maritime platforms. The accident that occurred on USS Forrestal exemplifies why it is critical that conventional munitions display maximum insensitivity when stowed, handled, carried or otherwise exposed to friendly forces and environments, but have sufficient energy/lethality to perform mission expectations reliably. This balance between sensitivity and performance is the focal point of the CSIM program.

A secondary factor imposed upon Navy and Marine platforms reflects ordnance performance and load-outs. To deliver the greatest lethality weapons, the highest performance munitions/energetic compositions are required. To assist the Navy in meeting this requirement, the advanced energetic materials program is exploring new ways of thinking about delivery of energy on target and ways to enhance performance while improving IM characteristics.

This program will establish the computational and synthetic chemistry foundations required to target the next generation of energetic ingredients capable of resisting inadvertent thermal and shock loading conditions based on the following derived synthesis hypotheses:
- Increase inter and intra molecular hydrogen bonding
- Delocalize electron density in nitro groups
- Utilize coulombic attractions to stabilize the ground-state structure
- Reduce the number of nitro groups
- Avoid high acidity
- Maximize crystal packing planarity

The implementation of CSIMs will:
- Enable compliance with insensitive munitions mandates
- Substantially enhance ship survivability in case of an accident or attack by eliminating the risk of sympathetic detonation
- Reduce the logistical and operational overburden currently imposed in order to satisfy load, stow, handle and launch non-compliant munitions, thus improving efficiency and reducing cost, with concomitant improvements in pace of operations and potential reduction in manning requirements

Research Challenges and Opportunities:
- Establish the connectivity between molecular structure, crystal morphology prediction and synthesis chemistry to provide IM-compliant energetic ingredients shock and thermal sensitivity
- Focus modeling and simulation to predict stable crystal structures/crystal morphology
- Establish methodologies to model, measure and predict molecular and crystal energetic material response to external shock and thermal modeling
- Validate design criteria for molecular stability as a function of insensitivity

AT A GLANCE

WHAT IS IT?
Insensitive munitions (IM) compliance is a requirement for all weapons in the fleet. Yet over 80 percent of the Department of Defense's munitions inventory is still non-compliant. CSIM technology will enable reduced sensitivity ordnance items for all fleet weapon systems.

HOW DOES IT WORK?
- With an expanded understanding of energetic materials initiation, combustion and detonation processes, coupled with knowledge about the types and quantities of crystal defects that exist in energetic materials, weapons designers will be able to develop improved compositions with improved insensitivity characteristics.
- Incorporating these physical inputs into advanced microscopic to mesoscopic modeling efforts will provide a rapid and accurate assessment of new compositions and formulations for advanced weapons system use and reduce IM test time and costs.
- Understanding the first principles is the basis for the development of more accurate large-scale simulations, thus reducing the number of dangerous and expensive tests necessary to qualify new munitions.

WHAT WILL IT ACCOMPLISH?
Mission requirements impose conflicting demands for weapon systems. The warfighter wants significant enhancements in delivery energy in compact volumes and also wants the weapon to be resistant to catastrophic failure in extremely stressful environments, including transportation, loading or storage on land or sea.

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Energetic Materials (EM)

EM weapon systems can be a game changer by increasing warfighters' lethality and area of dominance. Catastrophic damage improves battlefield damage assessment and reduces sorties. Equally powerful but smaller weapons optimize internal carry and facilitate higher weapon load-outs. Future new ordnance must be adaptable in size to fit a family of delivery systems, contain sufficient energy to defeat the target and be affordable.

The vast majority of ordinance systems use energetic materials to some degree. Energetic materials are used safely in actuators, demolition charges, aircrew escape, missile deployment applications, starter cartridges, gas generators and airbags. EM research, development and manufacturing technology encompass a broad science and engineering spectrum: basic molecular chemistry, detonation physics, combustion processes, pyrotechnic mapping, material science, lethality effects, process chemistry and engineering, and manufacturing technology.

Another EM thrust is related to advanced blast and propellant compositions which rely on ammonium perchlorate (AP) to assist combustion and detonation characteristics. Current AP systems have reached their engineered maximum efficiency, mandating the requirement for new ingredients to continue performance and sensitivity property advances.

Payoffs:
- Increase in performance
- Insensitive munitions-compliant
- Prolonged storage life (40–50 years)
- Safe handling
- Flexibility in size and weight
- Maximize energy on target compared to traditional weapons, resulting in enhanced lethality and improved weapon effectiveness

Research Challenges and Opportunities:
- New approaches to novel materials that maximize molecular design, synthesis efficiencies and predicted stabilities, and achieve performance goals
- Develop a new class of ingredients that can surpass the oxygen content of AP
- Develop macroscopic mechanical and chemical models and an understanding of molecule dynamics and strength/reactivity correlations
- Consistent processing and performance results; process research and development (commonly referred to as "scale-up"); areas of concern are safety and remote operations, critical thermal management, batch-to-batch reproducibility, standardized process for the chemistry and conditions and product quality and purity

AT A GLANCE

WHAT IS IT?
- Research to provide higher performance ordnance with acceptable insensitivity characteristics; includes explosives and propellants
- Focused on understanding of molecular design, synthesis, spectroscopic characterization and process research and development issues associated with energetic ingredient preparation

HOW DOES IT WORK?
- Understanding of EM initiation, combustion and detonation processes coupled with knowledge about types and quantities of crystal defects in EM
- Understanding first principles is the basis of more accurate large-scale simulations, reducing the number of tests necessary to qualify new munitions

WHAT WILL IT ACCOMPLISH?
- Military strike and logistics payoffs applicable across all ordnance systems
- Process refinement and scale-up activities providing consistent, reproducible and well-characterized materials to reduce acquisition cost
- Enable enhanced survivability, reduced operational and logistic burdens, improved operational tempo with respect to load out and sortie rates and reduced EM initiation sensitivity by external stimuli
- Combined kinetic and chemical energy in a weapon system with greatly enhanced lethality

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High Energy Dense Oxidizers (HEDO)

Advanced blast and propellant composition rely on ammonium perchlorate (AP) to assist combustion and detonation. Current AP systems have reached their engineered maximum efficiency, mandating the requirement for new ingredients to continue performance and sensitivity property advances.

The Office of Naval Research Advanced Reactive and Energetic Materials Program seeks to develop next-generation energetic materials (e.g., explosives, propellants and reactive materials) and technologies to enable substantially higher performance ordnance.

New ordnance must be affordable, adaptive in size to fit a family of delivery systems and able to contain sufficient energy to defeat the target. Science and technology must provide ordnance formulation flexibility to meet specific future naval mission requirements; comply with safety and environmental regulations; and achieve significant enhancements in delivery energy in compact volumes, while being resistant to catastrophic failure in extremely stressful environments, such as handling aboard carriers and long-term storage.

Future mission requirements impose challenging and conflicting demands for weapon systems, but advancing HEDOs ultimately will translate into greater national security as the Navy conducts its global mission.

Quantified payoffs include:
- Increase in system performance
- Insensitive munitions-compliant, resistant to catastrophic failures
- Prolonged storage life (40–50 years)
- Safe handling onboard ships
- Flexibility in the size and weight of weapon systems

Research Challenges and Opportunities:
- Develop a fundamental understanding of new molecule designs for HEDO synthesis with: ingredient density of 2 grams per cubic centimeter, melting point greater than 150° Celsius with a minimum number of synthesis steps
- Develop new classes of ingredients that can surpass the oxygen content of Ammonium Perchlorate (AP) and Nitro Glycerin (NG)

AT A GLANCE

WHAT IS IT?
The HEDO program is a research effort investigating next-generation oxidizer materials and concepts that will enable substantially higher-performing ordnance with acceptable insensitivity standards.

HOW DOES IT WORK?
- Technical efforts are directed toward molecular design, exploratory synthesis, investigation of physical and chemical properties and relationships, synthesis efficiencies and process research and development of advanced energetic ingredients.
- When inserted into ordnance/ propulsion systems, these new ingredients will increase system performance 10-fold while meeting insensitivity compliance objectives.

WHAT WILL IT ACCOMPLISH?
- The development of new oxidizer ingredients will yield enormous program payoffs across naval ordnance systems, such as torpedoes, warheads and strategic and tactical missile propellants.
- Process refinement and scale-up activities will provide consistent and reproducible materials for formulation applications.

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Electromagnetic Railgun

Innovative Naval Prototypes (INPs) foster game-changing and disruptive technologies ahead of the normal requirements process.
The Electromagnetic Railgun INP proof-of-concept demonstration at 32 mega-joule muzzle energy, has been achieved. A future weapon system at this energy level would be capable of launching a 100-plus nautical mile projectile.

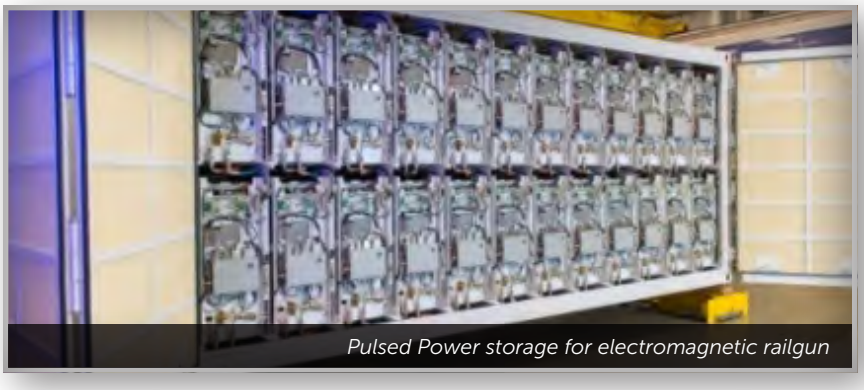
Phase I was focused on the development of launcher technology with adequate service life, development of reliable pulsed power technology and component risk reduction for the projectile.

Phase II will advance the technology for transition to an acquisition program.

Phase II technology efforts will concentrate on demonstrating a rep-rate fire capability. Thermal management techniques required for sustained firing rates will be developed for both the launcher system and the pulsed power system.

The railgun is a true game-changer for the warfighter. Wide-area coverage, exceptionally quick response and very deep magazines will extend the reach and lethality of ships armed with this technology.

Research Challenges and Opportunities:
- Advanced thermal management techniques for long slender metal rail structures
- Extended service life for materials and components in harsh environment
- High-strength, dielectric, structural materials
- High-speed, high-current metal-on-metal sliding electrical contact
- System interfaces between high-power loads and platform power distribution
- Compact pulsed power systems and power electronics
- High-conductivity, high-strength, low-density conductors
- Repetitive rate switches and control technologies
- Aerothermal protection systems for flight vehicles
- High-acceleration tolerant electronic components and structural materials



Pulsed Power storage for electromagnetic railgun

A projectile leaving the railgun barrel

AT A GLANCE

WHAT IS IT?
The EM Railgun launcher is a long-range weapon that fires projectiles using electricity instead of chemical propellants. Magnetic fields created by high electrical currents accelerate a sliding metal conductor, or armature, between two rails to launch projectiles at 4,500 mph.

HOW DOES IT WORK?
- Electricity generated by the ship is stored over several seconds in the pulsed power system.
- Next, an electric pulse is sent to the railgun, creating an electromagnetic force accelerating the projectile up to Mach 6.
- Using its extreme speed on impact, the kinetic energy warhead eliminates the hazards of high explosives in the ship and unexploded ordnance on the battlefield.

WHAT WILL IT ACCOMPLISH?
- With its increased velocity and extended range, the EM Railgun will give Sailors a multi-mission capability, allowing them to conduct precise naval surface fire support or land strikes; ship defense; and surface warfare to deter enemy vessels.
- Navy planners are targeting a 100-plus nautical mile initial capability.
- A variety of new and existing naval platforms are being studied for integration of a future tactical railgun system.

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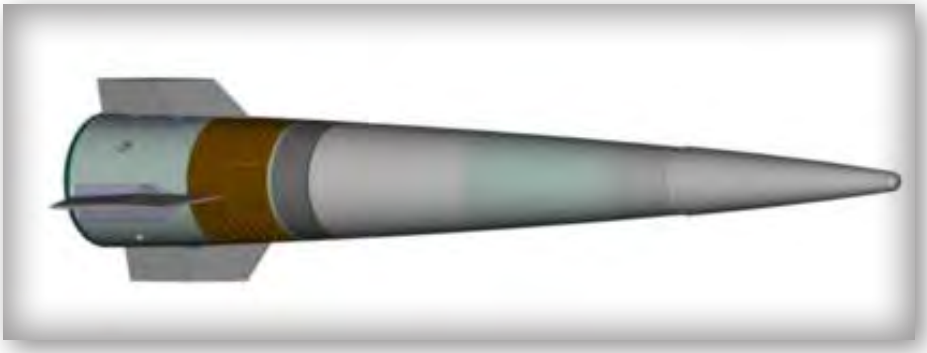

Hyper Velocity Projectile (HVP)

The Hyper Velocity Projectile (HVP) is a next-generation, common-design, low-drag, guided projectile capable of completing multiple missions from various gun systems such as the Navy 5-inch, 155-mm and future railguns. Types of missions performed will depend on the gun system and platform. The program goal is to address mission requirements in the areas of naval surface fire support, cruise missile defense, anti-surface warfare and other future naval mission areas. Mission performance will vary depending upon gun system, launcher and ship. HVP's low-drag, aerodynamic design enables high-velocity maneuverability and decreased time-to-target. These attributes, coupled with accurate guidance electronics, provide low-cost mission effectiveness against current threats and the ability to adapt to air and surface threats of the future.

The high-velocity, compact design eliminates the need for a rocket motor to extend gun range. Firing smaller, more accurate rounds improves danger-close/collateral damage requirements, and provides potential for deeper magazines and improved shipboard safety. Responsive wide-area coverage can be achieved using an HVP from both conventional gun systems and future railgun systems.

The common design will allow an HVP to be configured for multiple gun systems and to address different missions. The HVP is being designed to provide lethality and performance enhancements to current and future gun systems. An HVP for multiple systems will allow for future technology growth, while reducing development, production and total ownership costs.

Research Challenges and Opportunities:

- High acceleration-tolerant electronic components
- Lightweight, high-strength structural composites
- Miniature, high-density electronic components
- Safe, high-energy propellants compatible with shipboard operations
- Aerothermal protection systems for flight vehicles

AT A GLANCE

WHAT IS IT?
The HVP is a next-generation, common-design, low-drag, guided projectile capable of completing multiple missions from different gun systems.

HOW DOES IT WORK?
The HVP is configurable for various mission roles and gun systems through the use of multiple Integrated Launch Package components matched to a common airframe.

WHAT WILL IT ACCOMPLISH?
With its increased velocity, precision targeting and extended range, the HVP will provide the Navy with the capability to address a variety of current and future threats in the mission areas of naval surface fire support, anti-air and anti-surface warfare—using current and future gun systems.

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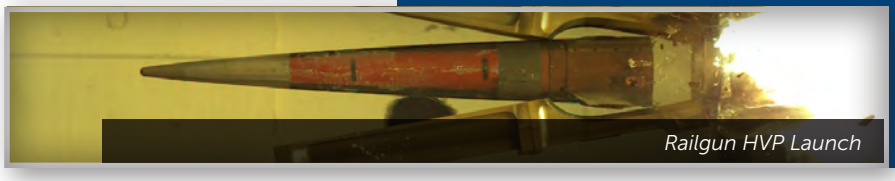
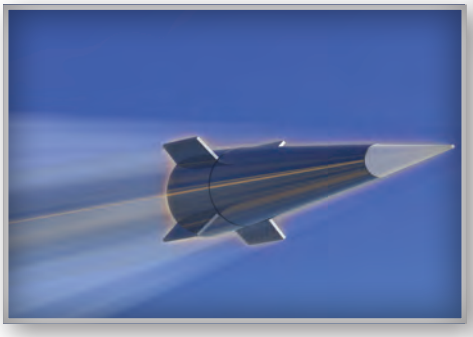
Mk 45 Mod 4 HVP Launch



Railgun HVP Launch

Hypersonic B/L Transition

Shock-B/L Interactions



Durable Hi-Temp Materials

High-Enthalpy Test Capability

Hypersonic Aerodynamics, Heat Transfer and Materials

Hypersonic flight (Mach 5 or higher) provides an unprecedented capability by simultaneously extending range and reducing transit time—enabling rapid reach and global targeting. Future high-speed weapons demand efficient aerodynamic designs that deploy lightweight, durable control surfaces and are capable of enduring the extreme exposure associated with hypersonic flight across a wide range of conditions.

Research Challenges and Opportunities:

- Boundary layer physics in shock-wave-dominated flows around highly swept or slender bodies
- Aero-thermo-elastic and/or aero-servo-elastic effects arising from control surface deflections at high-speeds
- Descriptions of high-speed boundary layer transition that unify theories across disparate external conditions
- Novel strategies for extending regions of laminar flow
- Advanced hypersonic aerodynamic design tools that incorporate modern predictions of transition pathways, freestream noise contributions, time/heating-dependent surface finish effects and unsteady aerodynamics

AT A GLANCE

WHAT IS IT?
The Hypersonic Aerodynamics program explores the impact of boundary layer transition on unsteady heating and loading in shock-boundary layer interactions; the capabilities that high enthalpy test facilities can provide; and novel methods for fabricating hypersonic vehicle configurations.

HOW DOES IT WORK?
Core investments include:

- Understanding boundary layer physics in shock-wave-dominated flows.
- Improving and expanding high-enthalpy test capability
- Advancing durable high-temperature material technology
- Research into aero-elastic effects arising from control surface deflections at high speeds

WHAT WILL IT ACCOMPLISH?
Hypersonic aerodynamic technology will equip the fleet with accurate, long-range weapon components able to survive high-temperature exposure for several minutes and thwart anti-access/area denial countermeasures.

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High-power Joint Electromagnetic Non-Kinetic Strike (HIJENKS)

The Office of Naval Research High Power Joint Electromagnetic Non-Kinetic Strike (HIJENKS) Leap Ahead effort will conduct research jointly with the Air Force Research Laboratory to develop and demonstrate an advanced high power microwave (HPM) payload. HPM weapons can provide combatant commanders with a unique capability to engage multiple targets with a scalable effects weapon applicable to a variety of warfighting missions. While enhancing the use of kinetic weapons, HIJENKS will provide an additional leap-ahead capability by creating options to prosecute targets previously restricted due to collateral damage concerns with a novel HPM payload integrated on an advanced airborne platform. The objective of HIJENKS is to advance the state-of-the-art within the Department of Defense (DoD) for HPM systems and components by focusing on innovative technologies for major HPM components, as well as lethality for targets of interest. A joint effort with the Air Force allows collaborative advancement in HPM technology maturation and accelerated progression of directed energy weapons (DEW).

HPM weapons create invisible beams of electromagnetic energy over a broad spectrum of radio and microwave frequencies that can cause a range of temporary or permanent effects on electronic targets. Examples include non-kinetic disabling of computer systems, damaging targeted electronics, disrupting security and industrial control systems, etc. Electromagnetic energy from an HPM weapon can couple to an electronic target directly through a transmit or receive element (like an antenna), or indirectly, through an aperture or cable points of entry (e.g., cracks, seams, external wires). Currents and voltages can be induced in target circuitry, resulting in erroneous signals, system lock-up, shutdown, loss of communication between systems and, sometimes, physical damage.

Research Challenges and Opportunities:

- Predictive weapon effects through target lethality, investigate HPRF coupling mechanisms, utilizing M&S and experimental validation
- Increased pulse repetition rate requires advancements in prime power, power electronics, and high voltage pulsed power switching
- High power, low profile / conformal antenna design and radome materials
- Electronic battle damage assessment and indicators (eBDA/eBDI)
- RF source development (Vacuum and Solid State) to investigate increased output power, higher rep-rate and frequency tunability for lethality effects

AT A GLANCE

WHAT IS IT?
HIJENKS will conduct joint research between the Office of Naval Research and the Air Force Research Laboratory to develop and demonstrate an advanced high power microwave (HPM) non-kinetic payload that will be integrated with an airborne platform to provide additional DoD capability in Electronic Attack (EA).

HOW DOES IT WORK?

- HPM weapons transmit electromagnetic energy (of varying waveforms and frequencies) through the atmosphere and cause circuit disruptions and/or system failures to electronic targets of interest.
- Research investment in component technologies will enable development of a compact, multi-pulse HPM system through focused S&T advancements in prime power, power conditioning, radio frequency (RF) sources and antennas.
- The objective is a non-kinetic, multi-shot, multi-target electronic attack weapon.

WHAT WILL IT ACCOMPLISH?

- The HIJENKS Program will provide non-kinetic strike options for electronic target disruption/ disable capability using HPM to address a wide variety of threats, with improved BDA and weaponeering capabilities.

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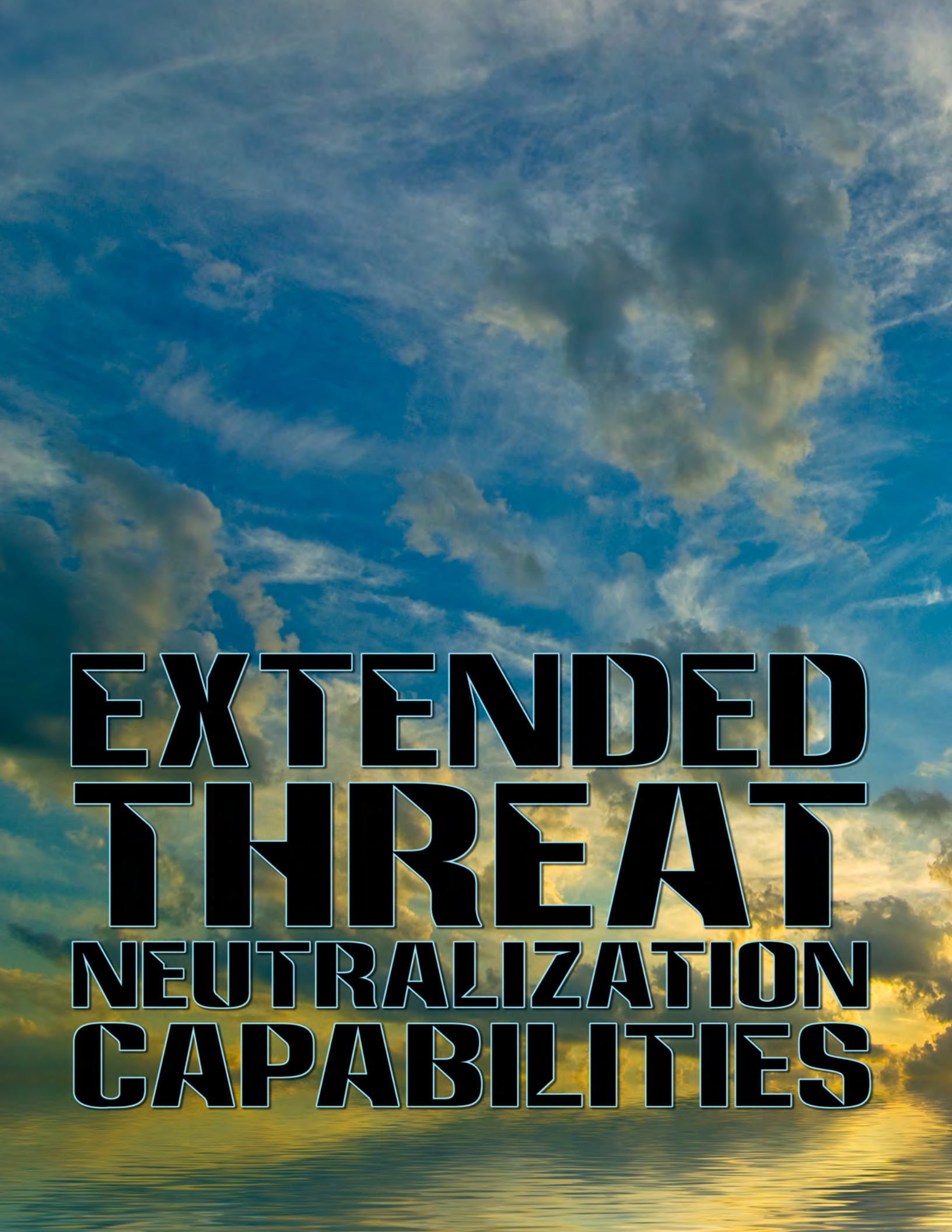
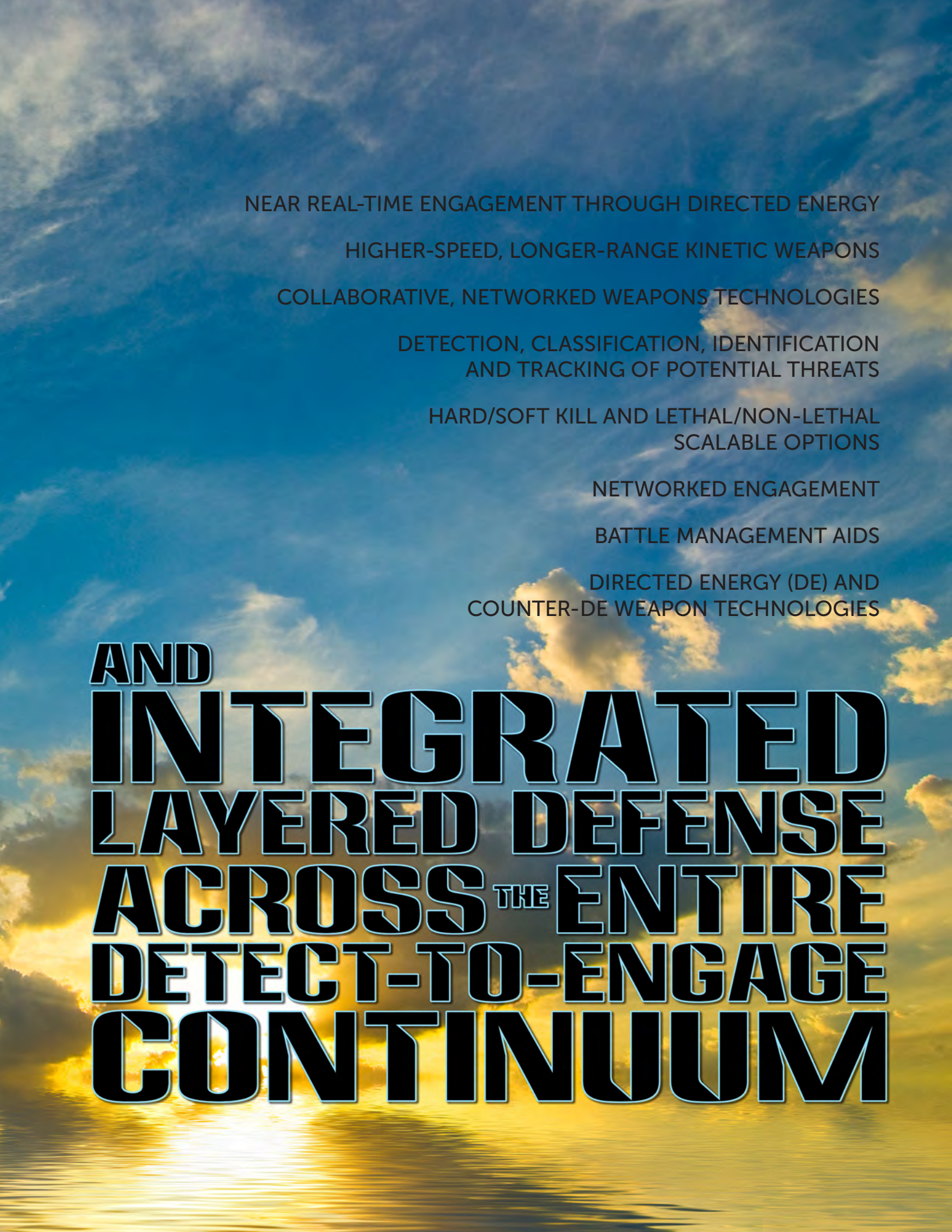
The aircraft carrier USS Theodore Roosevelt (CVN 71) transits the Pacific Ocean while conducting a tailored ship training availability off the coast of Southern California. ONR Code 35 programs enable basic and applied research to increase the range and lethality of sea-based aircraft and weapons. (April 30, 2017 U.S. Navy photo)


STERETT


EXTENDED
THREAT
NEUTRALIZATION
CAPABILITIES


NEAR REAL-TIME ENGAGEMENT THROUGH DIRECTED ENERGY
HIGHER-SPEED, LONGER-RANGE KINETIC WEAPONS
COLLABORATIVE, NETWORKED WEAPONS TECHNOLOGIES
DETECTION, CLASSIFICATION, IDENTIFICATION AND TRACKING OF POTENTIAL THREATS
HARD/SOFT KILL AND LETHAL/NON-LETHAL SCALABLE OPTIONS
NETWORKED ENGAGEMENT
BATTLE MANAGEMENT AIDS
DIRECTED ENERGY (DE) AND COUNTER-DE WEAPON TECHNOLOGIES
AND INTEGRATED LAYERED DEFENSE ACROSS THE ENTIRE DETECT-TO-ENGAGE CONTINUUM

Solid State Laser Technology Maturation Program (SSL-TM)

Solid State Laser Development
Solid State Laser (SSL) technology matured rapidly through development efforts in scientific and commercial sectors. The application of SSL technology to support surface combatant operations can enable new capabilities that enhance a wider range of other naval missions.

Solid State Laser Technology Maturation Program (SSL-TM)
The SSL-TM Program is focused on the design, build, test and demonstration of a 150 kW Laser Weapon System Demonstrator (LWSD) for naval surface ships. When delivered, the LWSD will execute live fire engagements during multiple scenarios, that include targets representing small boats, UAVs and ISR sensors. The LWSD implements an open systems architectural design concept that includes government-controlled interfaces. The open system elements offer the potential to cost effectively improve the system's capability by adding new modules or replacing modules with new technology as they become available. SSL-TM aligns its current science and technology program thresholds and objectives with future research developments, acquisition planning processes and requirements.

Navy Solid State Laser Simulated Experiment (SSL SIMEX)
Simulation experiments (SIMEX) are conducted to explore tactics, techniques and procedures (TTP) and mission effectiveness of Solid State Laser (SSL) employment. In October of 2016, at the MITRE National Security Experimentation Lab (NSEL), laser weapon systems augmented a simulated carrier strike group (CSG). The Navy specific scenarios examined engagement of swarming lethal UAVs, missiles and medium/high altitude UAVs, and included laser dazzling of sensors in operationally relevant threat scenarios. SIMEX results demonstrated that SSL weapons contribute to multiple mission areas across the kill chain; complement kinetic weapons by increasing the number of threats that could be engaged; and provide a significant capability for rapid engagement of threats through target identification and determination of intent at long ranges through high-power laser weapon beam director optics.

Research Challenges and Opportunities:
- Atmospheric propagation of high-energy lasers through maritime environments
- Ruggedized, damage-tolerant, self-aligning optical components
- Compact, robust, higher-efficiency, higher-energy laser technologies
- High-energy laser operator aides, including autonomous target identification and aim-point selection
- Energy storage and thermal management technologies that support extended engagements

AT A GLANCE

WHAT IS IT?
The ONR SSL-TM Program will develop and integrate high-energy laser weapon technologies to support at-sea demonstrations intended for ship-based self defense of Navy surface ships.

HOW DOES IT WORK?
- LASER means "Light Amplification by Stimulated Emission of Radiation." SSLs utilize solid state fiber-optic technology to amplify and focus light at long range
- Laser energy is transmitted to the target providing a range of effects from dazzling and jamming of sensors to structural damage.

WHAT ARE THE BENEFITS TO SAILORS AND MARINES?
- Deep-weapon magazine preserves kinetic weapons to address anti-access threats
- Rapid engagement of targets
- Low cost per engagement (compared to conventional kinetic weapons)
- Ability to tailor output to specific targets and missions with scalable effects
- Precise, low-collateral damage capabilities
- Reduced/Eliminated Energetics (No HAZMAT, explosives or propellants required)

WHAT WILL IT ACCOMPLISH?
- The SSL-TM Program will develop the Laser Weapon Demonstration System (LWSD) for surface Navy combatants to support precision targeting, near-real-time engagements and optically based battle-damage assessments.
- Lasers offer measured weapon effects, matched with deep magazine capabilities to defend against multiple, simultaneous arriving threats posed against Naval surface forces: including those from armed, unarmed intelligence, surveillance and reconnaissance or lethal unmanned aerial vehicles; light aircraft; asymmetric surface targets; small boats; small diameter rockets and missiles.
- The LWSD will examine precise target discrimination for enhanced aiming of existing guns and missiles.

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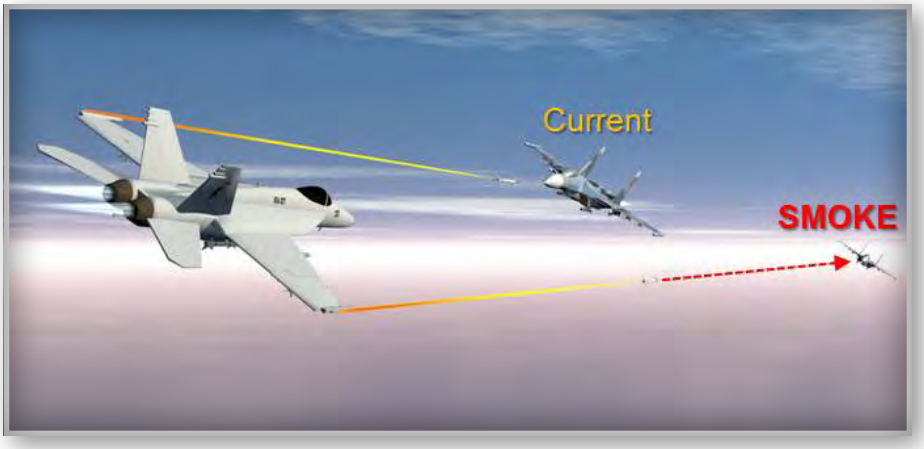

System Mission Optimized Kinematic Enhancement (SMOKE)

The SMOKE Future Naval Capability (FNC) product is developing missile propulsion and related subsystems for the improved kinematic performance and lethality of future advanced air-to-air missiles. To achieve this, the FNC is developing and integrating two advanced technologies: a two-pulse, end-burning rocket motor and a multi-function integrated energetic safety device (IESD). The kinematic and lethality performance enhancements are focused on improving the "no-escape range" and "time-to-target."

Many of the technologies being matured in this FNC are the fruits of the Office of Naval Research's investment in an earlier joint-service propulsion program known as Integrated High Payoff Rocket Propulsion Technology. The SMOKE propulsion effort will center on the development of a two-pulse, end-burning rocket motor to provide a significant increase in packaged total energy. Thrust output will be provided in two discrete pulses for optimization of kinematic performance throughout the expanded weapons engagement zone. Also, initiation of both rocket motor pulses along with the warhead's safe-arm-device, will be combined into a single mechanism—the multi-function IESD—again freeing up volume for the incorporation of additional propellant.

The SMOKE product is responding to higher kinematic performance and lethality requirements for advanced air-to-air weaponry as expressed by the fleet, and will provide the potential to achieve warfighter-defined tactical advantage for threats beyond 2020. This product will extend no-escape range, while decreasing time of flight to target at a significant range for air-to-air engagements. Additional benefits derived from the two-pulse, end-burn design and IESD will be improvement in insensitive munitions response.

Research Challenges and Opportunities:

- Two-pulse, highly loaded grain concept configuration with two-pulse, survivable- thrust vector control
- Distributed and command transmission fuse initiation methods

AT A GLANCE

WHAT IS IT?
The SMOKE Future Naval Capability will increase the kinematic performance and lethality of an advanced short-range air-to-air missile, enabling extended range and decreased time to target.

HOW DOES IT WORK?
The SMOKE FNC will achieve this through a combination of propulsion technologies that include a two-pulse, end-burning rocket motor and multi-function integrated energetic safety device.

WHAT WILL IT ACCOMPLISH?
By improving the kinematic performance of emerging air-to-air weapon systems over existing capabilities, SMOKE will ensure the warfighter maintains the tactical edge in air-to-air engagements against any peer competitor.

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Counter Air Defense (CAD) Improvements

The Counter Air Defense (CAD) Improvements Future Naval Capability (FNC) product is developing a missile propulsion system with substantially improved kinematic capabilities for the AGM-88E Extended Range Advanced Anti-Radiation Guided Missile (AARGM ER). To achieve this, CAD is developing and integrating three technologies: State-of-the-art (SOTA) high-energy propellants, highly loaded grain and low-erosion nozzles. The kinematic performance enhancements are focused on increasing the motor's total impulse and optimizing its thrust profile in order to provide extended range.

Many of the technologies being matured in this FNC are the fruits of the Office of Naval Research's investment in a joint-service propulsion program known as integrated high payoff rocket propulsion technology. SOTA propellant formulations from both industry and government will be considered on the basis of increased total impulse power achieved across the spectrum of operational environments. Highly loaded grain technologies will be investigated to enable the "end-burning" of the solid propellant, which will allow for higher volumetric loading of propellant within the rocket motor. Low-erosion materials for the nozzle design are needed to endure the greater erosive forces, temperatures and pressures yielded by the high energy propellant and longer duration burn time.

The CAD Improvements product is responding to higher kinematic and range performance requirements for AARGM ER as expressed by the fleet. In addition to substantially extending the missile's range, the highly loaded grain/end-burning design will provide an improvement to the missile's insensitive munitions characteristics.

The product is primarily focused on transition to the AGM-88E AARGM ER. In addition, it could serve as a solid rocket motor technology demonstrator for use in any potential future missile system development effort.

Research Challenges and Opportunities
- Advanced grain design for improved kinematic performance
- Incorporating the grain design technology into production missile systems

AT A GLANCE

WHAT IS IT?
The CAD Improvements Future Naval Capability (FNC) will increase the kinematic performance of the AGM-88E Extended Range Advanced Anti-Radiation Guided Missile (AARGM ER), enabling a significant extension in range capabilities.

HOW DOES IT WORK?
The CAD FNC will achieve this through a combination of propulsion technologies that include state-of-the-art propellants, highly loaded grain design and low-erosion nozzles.

WHAT WILL IT ACCOMPLISH?
By improving the kinematic performance of existing anti-radiation, air-to-ground weapon systems like the AARGM ER, CAD will ensure that U.S. forces maintain operational superiority over anti-access/area-denial capabilities of any peer competitor.

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Directed Energy Discovery & Invention Research Program

A directed energy weapon transmits electromagnetic energy from a source and delivers that energy to a target in a manner and/or quantity to purposely cause target damage, disruption or neutralization. The Directed Energy Discovery & Invention Research program (DE D&I) includes basic and applied research across three domains of directed energy: continuous-wave, high-energy lasers (HELs), ultra-short pulse lasers (USPLs), and high-power radio frequency (HPRF) science and technology. The technologies vary in their application and have specific characteristics determined by wavelength, energy content, repetition rate and waveform. Within the DE D&I program, research in all three domains focuses on novel and improved sources and supporting systems, propagation and atmospheric effects, and target effects.

Research Challenges and Opportunities:

High Energy Lasers (HEL)

- Beam control, adaptive optics, jitter and turbulence compensation
- Novel energy scaling/beam combining and improved energy efficiencies
- High damage threshold optical materials and coatings
- Atmospheric characterization and real-time, predictive modeling of laser performance in atmosphere
- Advanced laser gain media and novel architectures, eye safer sources
- Understanding of damage and novel lethality mechanisms

Ultra-Short Pulse Lasers (USPL)

- Novel laser-source technologies and power-amplification techniques, high power optics
- Atmospheric propagation: nonlinear Kerr focusing and time lensing, filamentation, beam control and adaptive optics, pulse diagnostics
- Characterization of USPL-matter interaction

High Power Radio Frequency (HPRF)

- Advanced and compact RF sources, antennas and pulsed power
- Waveform characterization, propagation and coupling
- In-band/out-of-band effects research, modeling, and experimentation
- Basic science of HPRF wave/matter interactions

AT A GLANCE

WHAT IS IT?
Directed Energy Discovery & Invention advances high energy laser, ultrashort pulse laser, and high power radio frequency science and technology.

HOW DOES IT WORK?
Directed energy systems transmit electromagnetic energy of varying waveforms, wavelengths, and repetition rates for specific effects at targets.

HEL
HEL illumination deposits energy on to a target, causing mostly thermal effects. The laser illumination melts or burns the illuminated target area as the energy accumulates over time.

USPL
USPLs produce short bursts of EM energy in durations less than a picosecond. The high power pulses cause an ablative effect on solid materials.

HPRF
Interactions between electronic circuits and electromagnetic energy over a broad spectrum of radio and microwave frequencies can cause a range of temporary and permanent effects on electronic systems.

WHAT WILL IT ACCOMPLISH?
The US Navy is investigating the use of DE to defend Navy assets from various threats. These threats require a broad and flexible response.

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Helicopter Active RPG Protection (HARP)

The HARP Future Naval Capability product will deliver a helicopter survivability capability to counter the threat posed by unguided munitions, specifically rocket-propelled grenades (RPGs). While the capabilities offered by HARP are applicable to a broad range of Navy and Marine Corps aircraft, the initial transition will focus on transport tilt-rotor and rotary-wing aircraft. These aircraft—due to their flight profiles—are particularly vulnerable to low-tech, unguided munitions.

HARP will provide a hard-kill RPG countermeasure system that will permit intercept and defeat of multiple incoming RPGs at a safe range from the helicopter. Cueing from existing or planned aircraft survivability equipment sensors will trigger HARP's tracking and guidance sensors to command hard-kill countermeasures to intercept single or multiple RPGs.

The science and technology issues that will be addressed in HARP include: the trade between warhead size and lethality and safety of own aircraft, other rotor-craft in the vicinity and blue forces on the ground; the trade between having a short reaction time but maintaining high-accuracy spatial targeting; and the trade between performance, cost and keeping a small footprint on the aircraft.

Research Challenges and Opportunities
- Hard-kill interceptor countermeasure
- Interceptor-launcher-aircraft interfaces
- Tracker/intercept fire control

AT A GLANCE

WHAT IS IT?
The HARP Future Naval Capability will develop and demonstrate a prototype hard kill countermeasure system for defeating rocket-propelled grenades (RPGs) that target helicopters.

HOW DOES IT WORK?
Making maximum use of the existing Aircraft Survivability Equipment suite, HARP will launch, track and guide a unique expendable to intercept and defeat RPGs.

WHAT WILL IT ACCOMPLISH?
Current countermeasure techniques have no effectiveness against RPGs, which do not depend upon seeker information for guidance. HARP will provide a hard-kill countermeasure solution to fill the material capability gap against this historically deadly family of weapons.

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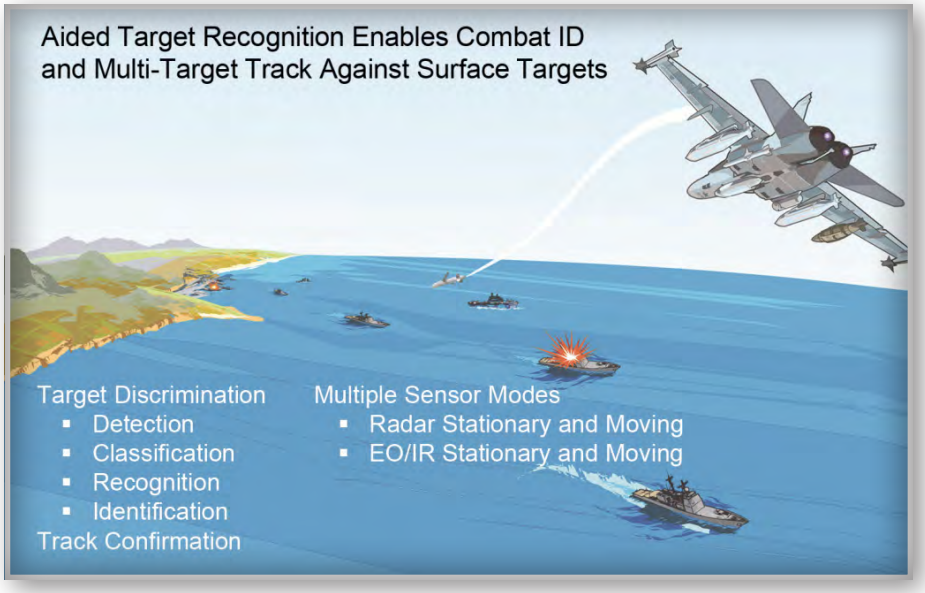

Strike Accelerator

The Strike Accelerator Future Naval Capability (FNC) product will develop and mature an Aided Target Recognition (AiTR) system to provide F/A-18 aircrews with a high decision rate and high classification/recognition/identification confidence against adversary surface combatants. This capability will automatically recognize and identify ships in port and ships at sea, even in a cluttered littoral environment. By reducing manual data search and target decision time by a factor of 10 to 100, Strike Accelerator will shorten key links in the kill chain—thus enabling traversal of kill chain in minutes and supporting combat identification and multi-moving target track aboard the F/A-18 E/F and EA-18G aircraft. Strike Accelerator will enable the Hornet/Growler platforms to engage multiple desired points of impact per pass with their precision weapons.

Stationary and moving maritime target data are provided to Strike Accelerator by theF/A-18's Active Electronically Scanned Array Radar and Advanced Targeting Forward Looking Infrared optics pod. Strike Accelerator's advanced AiTR algorithms and multi-look, adaptive and hierarchical architecture will process the raw data inputs and produce outputs at four levels of fidelity for the pilot/aircrew. At the lowest fidelity level—target detection—targets are distinguished from non-targets in the sensor data. Target discrimination outputs then increase in fidelity from classification to recognition and finally to the highest fidelity level of identification. Target discrimination output decisions are passed on to the aircrew as reliable processed information for use in determining the need for further action.

Strike Accelerator's adaptive discrimination will respond to the mission environment by tuning the AiTR system parameters. Multi-look discrimination will fuse the target decisions from multiple sensor images into a single decision. The multiple looks may come from the same sensor at different times or from different on-board sensors/modes or potentially from networked off-board sensors.

Research Challenges and Opportunities:
- Automated high-accuracy radar and optical target detection, classification, recognition and identification
- Hierarchical target discrimination
- Adaptive target discrimination

AT A GLANCE

WHAT IS IT?
The Strike Accelerator Future Naval Capability will accelerate the kill chain and enable rapid target identification and multiple-target engagement for the F/A-18E/F/G.

HOW DOES IT WORK?
Radar and infrared data on shipping are processed and classified or identified by an Aided Target Recognition System.

The high-confidence output is quickly passed to the aircrew who make the final target determination and engagement decision.

WHAT WILL IT ACCOMPLISH?
Speeds up target prosecution by reducing the data search and decision making that the aircrew must complete to execute combat identification and multi-target track.

This will allow the targeting of precision weapons against multiple stationary or moving targets by a single platform in a single pass in a crowded littoral environment.

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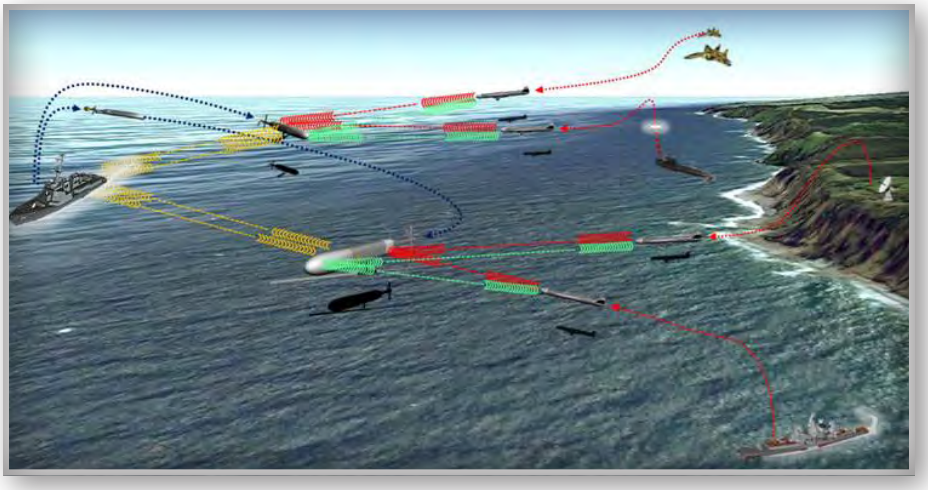

Ship-launched Electronic Warfare Extended Endurance Decoy (SEWEED)

Navy ships are subject to missile attacks that may be short notice and grouped to overwhelm defenses. Defenses include hard-kill, onboard and offboard electronic warfare (EW); all three combined are needed to be most effective. Current offboard (decoy) platforms have limitations in availability, duration of operation or performance. The PEO IWS 2.0 Advanced Offboard EW program is the Navy initiative that is planning, developing and fielding major capability improvements in this area.

The SEWEED Future Naval Capability (FNC) program seeks to develop a rotary-wing platform that combines quick reaction with long endurance and serves as an EW payload platform. The EW payload itself is not part of the SEWEED program, but integration provisions are.

SEWEED technologies are drawn from years of experience at the Naval Research Laboratory (NRL) in designing and demonstrating ship-launched decoys. Industry will be asked to further develop and integrate these technologies as appropriate into a design that can be developed into an operational system.

SEWEED is intended to be stored in and launched from a specially designed launch system, which will be located in the EW area of a naval ship. Alternatively, it could be made compatible with the vertical launch system.

NRL is the SEWEED vehicle developer, and will deliver design data and test results in a data package when the program reaches Technology Readiness Level 6.

Research Challenges and Opportunities:
- Industry will be kept informed through industry days as the program progresses.

AT A GLANCE

WHAT IS IT?
SEWEED is a quick-reaction, long-acting air vehicle platform that can carry an electronic warfare (EW) payload for ship self-defense.

HOW DOES IT WORK?
Concept of operations:
- Incoming threat detected
- SEWEED decoy rocket launched from ship
- Ship EW systems control decoy position and tactics
- Each SEWEED could address multiple threats in field of view
- Decoys remain aloft for extended protection

WHAT WILL IT ACCOMPLISH?
- Provide a critical enabler for defense of any naval ship against anti-ship cruise missiles

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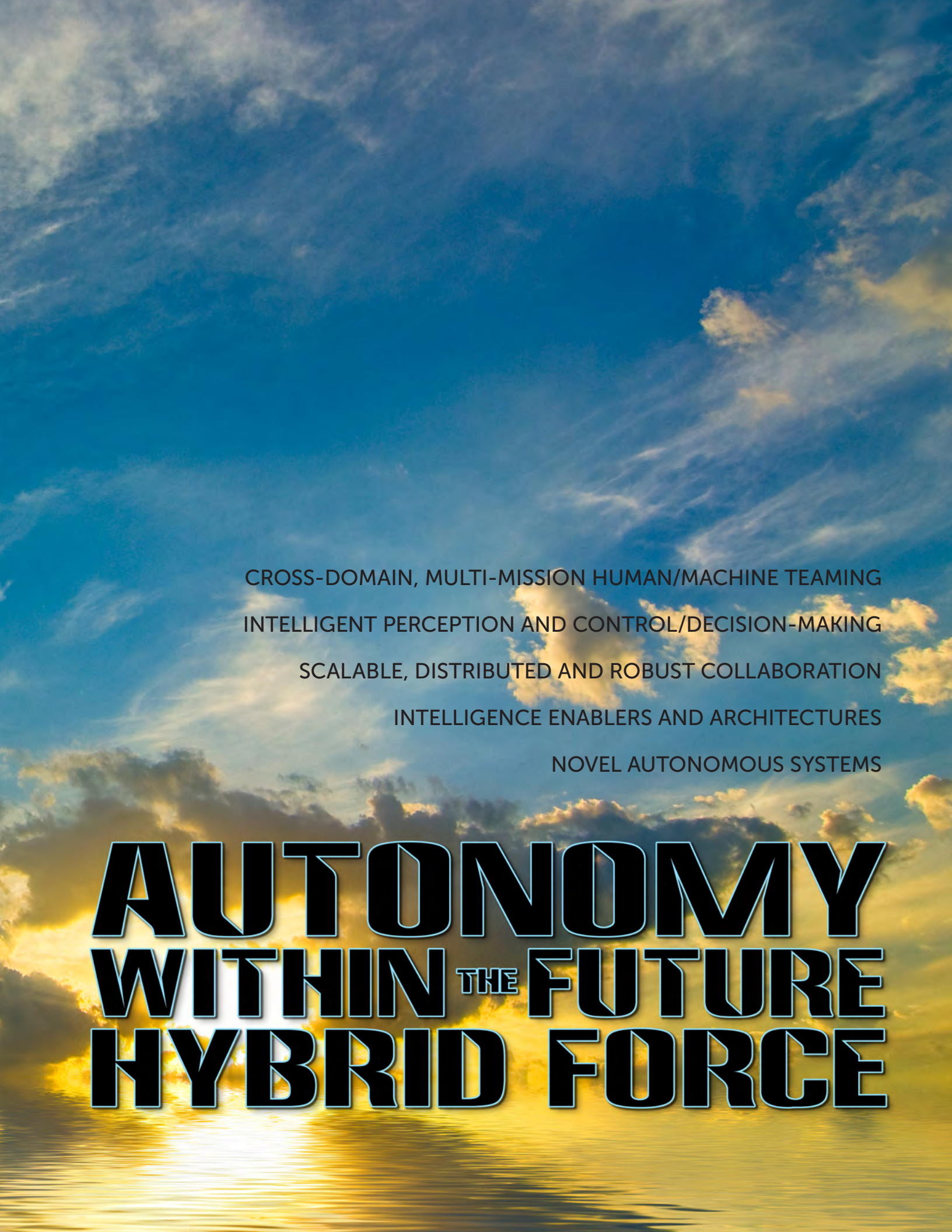
An F/A-18E Super Hornet assigned to the "Gladiators" of Training Squadron (VFA) 106 launches from the aircraft carrier USS Dwight D. Eisenhower (CVN 69). The ship is conducting aircraft carrier qualifications in the Atlantic Ocean. ONR Code 35 programs enable basic and applied research to provide higher-speed and longer range weapons for aircraft such as the F/A-18E. (March 14, 2017 U.S. Navy photo)


CROSS-DOMAIN, MULTI-MISSION HUMAN/MACHINE TEAMING
INTELLIGENT PERCEPTION AND CONTROL/DECISION-MAKING
SCALABLE, DISTRIBUTED AND ROBUST COLLABORATION
INTELLIGENCE ENABLERS AND ARCHITECTURES
NOVEL AUTONOMOUS SYSTEMS
AUTONOMY
WITHIN THE FUTURE
HYBRID FORCE

Science of Autonomy

The Science of Autonomy effort addresses critical multidisciplinary research challenges that cut across different Office of Naval Research (ONR) departments and warfighting areas/domains. This involves different autonomous system domains that have traditionally been somewhat separated (air, sea, undersea, ground), control theory, computational intelligence, human factors and related fields such as biology/animal behavior/cognition, economics/management theory, cognitive science/psychology, and neuroscience.

The research is focused on making progress on a set of autonomy technical challenges that were identified in a series of ONR/Naval Research Laboratory workshops. The challenges are in the four interrelated areas of Human Collaboration with Autonomous Systems, Perception and Intelligent Decision-Making, Scalable Distributed Collaboration and Intelligent Architectures. These challenges need to be addressed relative to critical aspects of the naval domain, including: (1) Operations in spatially and temporally variable and uncertain environments with limited manning, communications and other resources; (2) users with a wide range of skills and experience including getting unmanned system services to support small tactical units; (3) diverse environments encompassing air, sea surface, undersea and ground systems and hybrid concepts in between; (4) platforms with highly limited and intermittent communications; (5) complex missions with heterogeneous platforms and sensors, including significant differences in physical and sensing capabilities; (6) rapid and dynamic responses to user needs and changes in the operating space; and (7) the need for automation to explain its capabilities to the user and reliably execute the required tasks in the required time.

Examples of multidisciplinary research include: (1) a control engineer working with a neuroscientist to develop spatial understanding approaches for autonomous systems that fit human semantic models and could be used to create unmanned aerial vehicle "wingmen" for dismounted Marines; (2) biologists and engineers using models of social interactions in animal groups that allow individuals to access higher-order computational abilities at the collective level and make good decisions despite uncertainty; and (3) biologists, psychologists and engineers applying behavioral and cognitive models of predator-prey relationships to engineered systems for intelligence, surveillance of reconnaissance of large, complex areas by heterogeneous unmanned systems.

Research Challenges and Opportunities:

- Scalable, self-organizing, survivable, organizational structure/hierarchy of heterogeneous unmanned vehicles appropriate to naval mission domains
- Autonomous learning, reasoning and decision making in unstructured, dynamic and uncertain environments
- Human interaction/collaboration including understanding intent and actions of human team members, adversaries and bystanders
- Organic perception/understanding to support decision making, reasoning and actions in a complex, dynamic world

AT A GLANCE

WHAT IS IT?
Addresses critical multidisciplinary autonomy challenges that cut across different ONR departments and warfighting areas/domains, including air, sea, undersea and ground.

HOW DOES IT WORK?
Focused on four interrelated areas:
1. Human Collaboration with Autonomous Systems
2. Perception and Intelligent Decision-Making
3. Scalable Distributed Collaboration
4. Intelligent Architectures
   - Develops collaborations between researchers in different autonomous system domains that have traditionally been somewhat separated (air, sea, undersea, ground), control theory, computational intelligence, human factors, biology, economics, cognitive science/psychology and neuroscience

WHAT WILL IT ACCOMPLISH?
Autonomous operations in many naval domains, for many mission types and on multiple platforms that can:
- Operate as part of a hybrid force with manned systems and platforms
- Maintain survivability through decentralized assets/redundancy
- Reduce the need to place personnel and high-value assets in high-threat areas
- Reduce manning and comms requirements
- Expand the operational envelope of naval forces, provide force multiplication or replace existing capability with less expensive alternatives.

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Unmanned Air System Autonomy

Research in intelligent autonomy focuses on technologies for safe, reliable and scalable control of heterogeneous unmanned naval systems based on high-level mission tasking. This includes collaborative and shared use of unmanned systems by a variety of operators and users of unmanned system services. An important part of this is to allow unmanned air systems to be operated in a way more compatible to manned aircraft (i.e.,without special restrictions or procedures) in naval missions and environments. Applied research efforts focus on airspace management, ground/shipboard operations, supervisory control of teams of heterogeneous unmanned systems, optimizing shared use of multiple unmanned system resources by multiple requesters collaborating among themselves and with multiple operators, and allowing small unit users to rapidly input mission tasking based on high-level intelligence requirements only.

Key research areas include:
Safe shipboard and airspace operations integrated with manned aircraft for naval missions. This includes development of an integrated system that supports the human need for "big picture" situational awareness for flight deck control and launch operations, as well as local interaction between unmanned vehicles and deck handlers. It also includes the development of replanning and execution tools for airspace and mission management of a family of unmanned systems.
New tactical roles for unmanned air systems such as riverine, under the canopy in heavy foliage, casualty evacuation and as a wingman for dismounted Marines. This includes basic research in perception-based control in complex environments and applied research to support flying in complex riverine areas under the canopy by utilizing vision-based navigation and path planning and non-GPS landing at unprepared sites in complex environments (weather, obstacles, slopes, terrain, etc.).

Sustainable operations in challenging weather and environmental conditions, including harvesting atmospheric energy and flight in challenging weather.
Control of large numbers of heterogeneous unmanned systems in complex airspaces, including supporting the human operator in managing complex multi-vehicle operations.

Shared and distributed control to get unmanned air system services to the tactical edge.

Research Challenges and Opportunities:
- Biologically inspired, perception-based control for safe operation around complex, unknown and unstructured terrain and humans
- Adaptive and robust multi-unmanned vehicle collaboration approaches for operations over complex areas and in time-critical applications
- Human interaction and collaboration approaches for managing large numbers of unmanned vehicles
- Analytic tools for analysis/verification and validation that allow for prediction of complex autonomy approaches under realistic assumptions

AT A GLANCE

WHAT IS IT?
Basic and applied research in autonomous control and collaborative control, with a focus on key challenges of naval air systems and heterogeneous naval teams that include air systems.

HOW DOES IT WORK?
- Safe shipboard and airspace operations integrated with manned aircraft for naval missions
- Control of large numbers of heterogeneous unmanned systems in complex airspaces
- Sustainable operations in challenging weather and environmental conditions
- New tactical roles for unmanned air systems such as riverine, under the canopy in heavy foliage, casualty evacuation and as a wingman for dismounted Marines
- Shared and distributed control to get unmanned air system services to the tactical edge

WHAT WILL IT ACCOMPLISH?
- Control large numbers of unmanned systems that can be deployed in great numbers
- Allow safe and sustainable operations more like manned aircraft on naval missions and in challenging environments/ weather conditions
- Reduce manning for unmanned system operations
- Support a wide range of users including small ships, Marine Corp/SOF small units, maritime patrol aircraft, submarines, etc.
- Increase autonomous system services out to the tactical edge

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Autonomous Aerial Cargo/ Utility System (AACUS)

AACUS is an Office of Naval Research Innovative Naval Prototype (INP) program. The need for AACUS stems primarily from Marine Corps requirements for "an alternate means to provide time-sensitive logistics support to greatly dispersed locations. Cargo UASs can provide a solution to move tailored ammunition, supplies, fuel/water or weapons packages in adverse weather from the sea or ashore over harsh terrain as required (24/7)." (Universal Needs Statement (UNS) for the Cargo UAS)

Vertical takeoff and landing (VTOL) systems have significant advantages over other means of resupply, including avoidance of improvised explosive devices and greater speed over trucks that are often limited by hostile conditions and manning constraints, which are mitigated when using unmanned aerial vehicles. Recent progress has been made in Cargo Unmanned Aerial System (CUAS) autonomous cargo drops and deliveries; however, such advances rely upon the presence of prepared, obstacle-free landing sites as well as trained CUAS operators with some level of control over flight parameters.

AACUS represents a substantial leap over both present-day operations, as well as other near-term CUAS development programs, as it is focused on autonomous obstacle avoidance and unprepared landing site selection with precision landing capabilities including contingency management, in route re-planning, and multiple mission execution. AACUS includes a goal-based supervisory control component such that any field personnel can request and negotiate a desired landing site using an intuitive hand-held field device interface. Moreover, this system will communicate with ground personnel for seamless and safe loading and unloading.

Another unique aspect of AACUS is its portability–this system will be VTOL platform-agnostic, with an associated open architecture framework allowing it to be used across different air vehicle platforms.

Research Challenges and Opportunities:

- Long Range Broad Agency Announcement (BAA) for Navy and Marine Corps Science and Technology BAA N00014-16-R-BA01

AT A GLANCE

WHAT IS IT?
The AACUS program explores advanced autonomous capabilities for reliable resupply/retrograde by an unmanned air vehicle under adverse conditions. AACUS is a sensor suite and software package that enables key features, included a vehicle autonomously avoiding obstacles while finding and landing at an unprepared landing site in dynamic conditions, with goal-directed supervisory control by a field operator from an intuitive hand-held field device.

WHAT WILL IT ACCOMPLISH?

- Due to an open architecture approach for global management of mission planning data, AACUS technologies will be platform agnostic and transferable as an autonomy modification kit for rotary wing aircraft to both new and legacy unmanned aerial systems (UASs) and convert manned legacy airframes to enable an "optionally manned" capability.
- AACUS-enabled UASs and optionally manned aircraft will rapidly respond to requests for support and autonomously navigate to the area, and detect and negotiate precision landing sites in potentially hostile settings.
- Such missions could require significant obstacle and threat avoidance with aggressive maneuvering in the descent-to-land phase.

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Doing Business with Code 35

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For more information, please visit **www.onr.navy.mil.**
On this site, you will find links to program opportunities, including:

Broad Agency Announcements (BAAs)
A BAA announces an agency's research interests, including criteria for selecting proposals and soliciting the participation of all offers capable of satisfying the government's needs.

Requests for Information (RFIs)
An RFI is used when a government agency does not presently intend to award a contract but wants to obtain price, delivery, other market information or capabilities for planning purposes. Responses to these notices are not offers and cannot be accepted by the government to form a binding contract.

Requests for Proposals (RFPs)
An RFP is used in negotiated acquisitions to communicate government requirements to prospective contractors and to solicit proposals.

Requests for Quotes (RFQs)
An RFQ is a solicitation that provides, in exacting detail, a list or description of all relevant parameters of the requirement. RFQs are best suited to commercial products and services.

Special Notices
These notices provide information about Industry Days, other events and other information that, while not captured in one of the other funding announcements, may be relevant to a given opportunity.

Multiple-Award Task Order Contracts (MATOCs)
MATOCs were previously used by ONR for acquiring support services. ONR now uses SeaPort-e for acquiring support services.

SeaPort-e
This portal is the Navy's electronic platform for acquiring support services in 22 functional areas, including engineering, financial management and program management.

Please read and follow precisely the instructions for submitting paperwork. Forms must be completed, and formats outlined in the instructions must be followed or the paperwork will be returned. Should you have any questions, please reach out to the contact cited in the instructions.

Solid State Laser

The military began experimenting with laser weapons in the late 1970s. Although they demonstrated high output levels, these systems often were very large, difficult to integrate, costly, and had insufficient target engagement ranges. With the advent of solid-state laser technologies, systems improved in size, weight and power to make shipboard compatibility practical.

Solid-state laser weapons cost about $1 per shot to fire. They allow escalating power projection (deter, damage or destroy) and are highly effective for countering unmanned aerial vehicles and small boats. They have deep magazines, depending only on a ship's electrical power and cooling to fire.

Higher-power solid-state lasers are under development, providing defense against more robust threats.

The Autonomous Aerial Cargo/ Utility System (AACUS) enabled UH-1H approaches LZ Egret at Marine Corps Base Quantico during flight testing on May 25, 2017. The Office of Naval Research program consists of a sensor and software package that enables autonomous capabilities in rotary-wing aircraft. AACUS allows the Marine Corps to rapidly resupply forces on the front lines in austere, unprepared landing zones, with minimal training required for Marines on the ground.

For more information, please contact

Office of Naval Research
ONR Code 35
875 N. Randolph Street
Arlington, Virginia 22203-1995

www.onr.navy.mil/Science-Technology/Departments/Code-35.aspx

The Naval Air Warfare and Weapons (Code 35) Department supports Navy and Marine Corps needs, fostering basic, applied and advanced research in support of the Sea-Based Aviation National Naval Responsibility as well as directed energy, electromagnetic launch and high-speed conventional air and surface weapons.